PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

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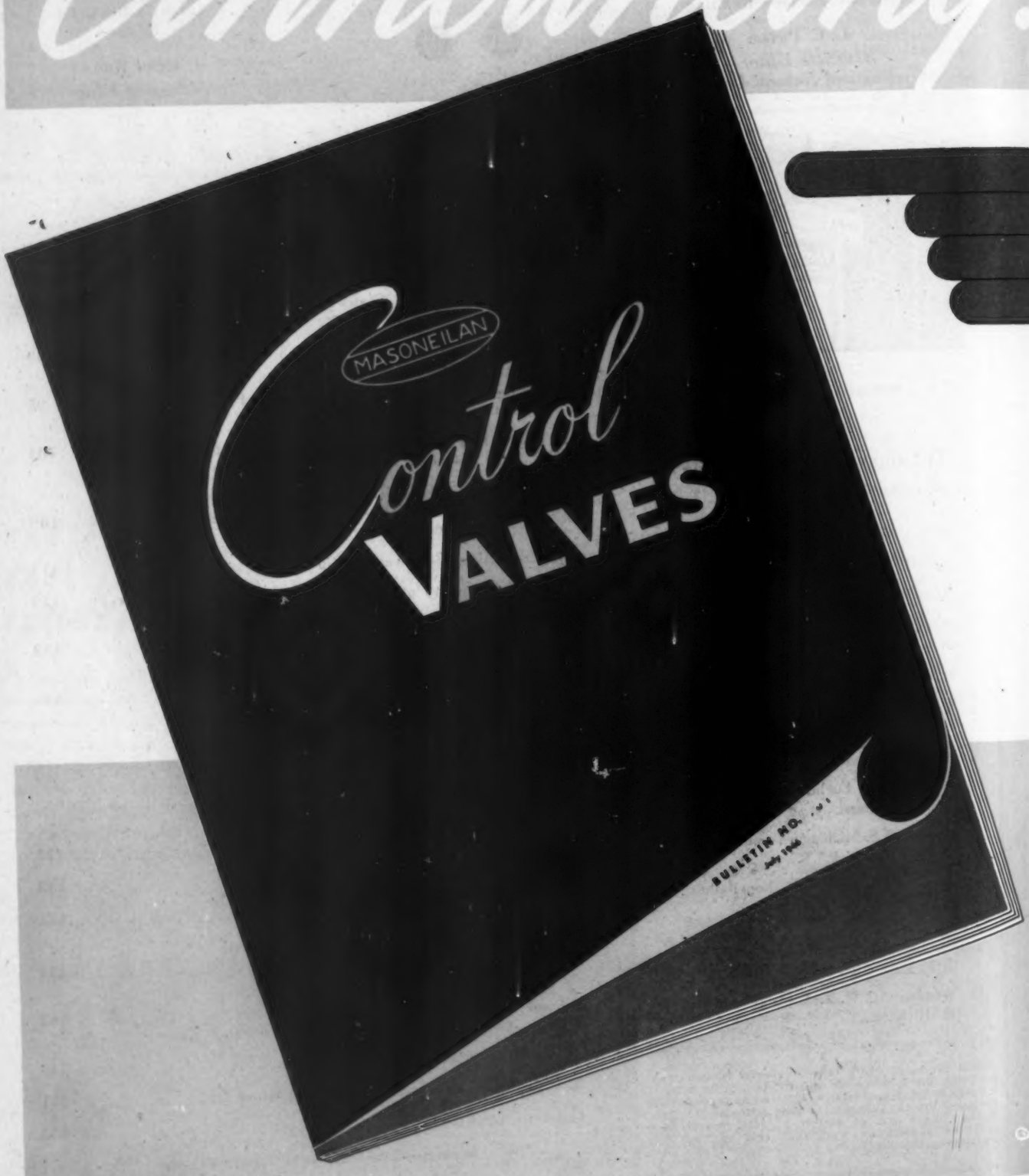

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A GULF PUBLISHING COMPANY PUBLICATION

THE LOOK BOX

BY NIGHT a young dog had the run of a back yard. By day he was chained and had the advantage of adequate housing. The combination was supposed to give the owner protection of property, since the dog was of a breed given to barking.

Plea For Shackles

Since Sunday activity in that household did not require prompt opening of gates, the dog had longer hours of freedom once each week. This privilege was acceptable for many months. Then one Sunday the master heard his animal whimpering. Upon investigating he found the dog standing close by the chain. Whimpering and quivering stood what had been selected as a protector of property and his nerves were not quieted until the chain was attached.

Thus protection, darkness and a fence by night and a leash by day, had transformed a normal dog into a shrinking cowardly animal.

How like that dog are the American people as they stand whimpering in the early days of July, 1946, and plead that the leash of price control be returned to their necks!

Can it be that the American citizen has come to a point where he accepts the proposition that he is not capable of taking care of himself?

Bureaucrats have been telling us that. They insist that only a man or a clique in Washington can assure the American citizen of justice from his neighbors. The willingness to submit to the scheme of price control indicates that most men doubt their ability of self protection at the market place.

For 166 years the American citizen took care of his own buying and selling. As a consequence he had more goods of better quality and at lower prices than any other people.

Has all of that been forgotten in four years of the price control leash?

ALTHOUGH it is not reasonable to judge the results of atomic destruction at Bikini this early, it is to be hoped that first indications are substantiated and that it is proved that the atom bomb is not so destructive as was anticipated.

First Reports

Such a finding will be a tonic, even to the scientific mind, which unfortunately is yielding to the popular impression that nuclear fission assures disaster. Somehow man has come to assume that dealing with the atom is akin to dealing with some secret of the Almighty. Men act as if they are guilty of prying where they should not have sought information. Atomic energy is too much accepted as beyond the proper sphere of mankind.

Nothing could be more foolish. Basically the search for the secret of the atom is as worthy as seeking control of the typhoid germ. Man has committed no sin in releasing the energy inherent in the atom.

Only his attitude can convert the knowledge of the atom into disaster. If men accept fission as

Dowtherm on the job!

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CHEMICALS INDISPENSABLE TO INDUSTRY AND AGRICULTURE

worthy of only destruction, then a mistake has been made. The catapult and gunpowder each placed in the hands of mankind the means for destroying civilization. What men do with a tool is not determined by the nature of the tool. If restricted to the bomb, nuclear fission is a mistake and man is unworthy of what he has produced.

The first reports from the Marshall Islands indicates that this bomb is not the so all-destructive as anticipated. Perhaps this will give men the courage to look upon atomic energy from other viewpoints. We need not worry about the destructive qualities of atomic energy. Records in Japan are evidence this energy can be destructive.

What atomic energy needs now is some attention from men who know how detrimental it can be and know in addition how beneficial it can be. Given that kind of attention, atomic energy will elevate civilization.

The Longer Viewpoint

KEEPING natural gas at home under the hope that industry will come into full bloom where fuel is cheap may prove sorry policy in view of what can be done in the gasifying coal. An indication of trends can be had out of the testimony of P. C. Kieth, president of Hydrocarbon Research, Inc., before the Federal Power Commission in June.

"If," he warned, "the southwestern producing states do not export their gas while there is demand for it, they may wake up 10 or 15 years from now and find that the East is gasifying coal."

He told the commission that plants located in the Eastern coal regions can produce gas of high Btu content and supply it at 24.2 cents per thousand cubic feet in New York City.

Somehow an impression has gained standing that natural gas can ignore ordinary economics since it is a product that defies substitutes and ignores competition. Nothing could be more disastrous than for natural gas to fall into such sponsorship.

There have been classic instances of free natural gas being held out as inducement for industrial development. The industrial plants did not arrive in the gas areas simply because free fuel over a period did not overcome other handicaps. As a fuel, natural gas faces ample competition.

More recently the product has had the defense of a clique, chiefly political, which insists that natural gas should be held under artificially high prices since it is of such high value as chemical raw material. It is coming into chemical use but holding it at higher prices hinders rather than helps this trend.

Furthermore there is a limit to the amount of natural gas that can be used economically as raw material. Somehow the men who plan things economic seems to forget that an industry grows slowly, even when conditions such as low cost predominate. This testimony of Warren M. Watson, secretary of the Manufacturing Chemists Association, before FPC is typical of inadequate presentation:

"Natural gas and its components are of greater importance as raw materials than they are as a simple fuel," pointing out that 10,000,000 cubic feet of gas burned daily as fuel has a value of $730,000 in a year whereas the same amount of gas for chemical use would justify the investment of $25,000,000 in a plant employing about 1500 people and producing 200,000,000 pounds of chemical products a year.

The figures doubtless are true. What the witness did not explain was the limited application to processing plants to each 10,000,000 cubic feet of natural gas now available. The industry is not going to absorb the available raw material soon and that condition the gas producer must accept.

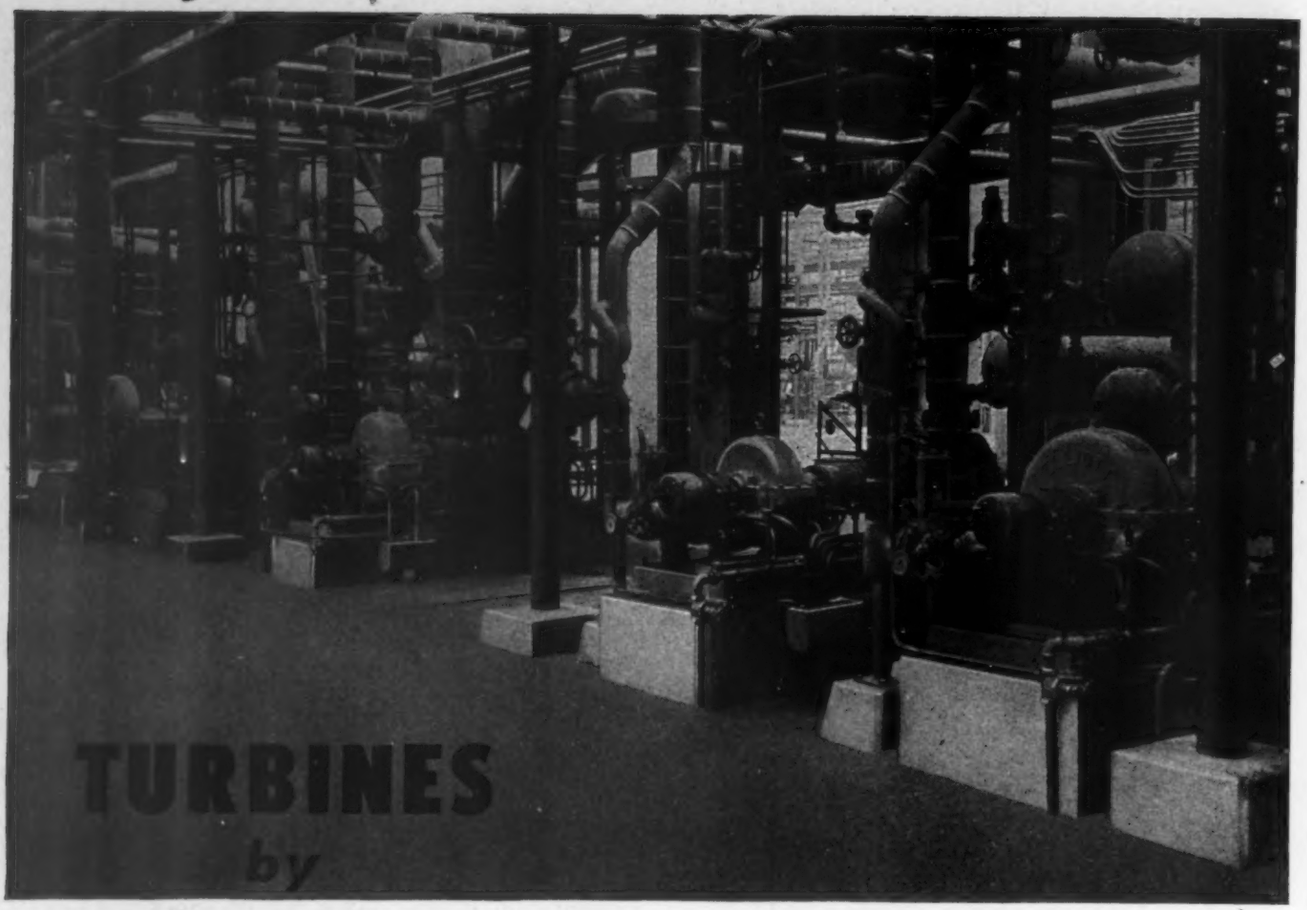
Volume Index

INDEXING the annual volume of a publication like PETROLEUM REFINER is a problem for experts—and the compilers of indexes are amateurs. They are amateurs because the work is done by people who are busy at other things—there is not enough index work to specialize. That is the reason we were interested to know the reaction of readers to the change we made in presentation of the index to the 1945 volume [PETROLEUM REFINER, *December, 1945*]. We invited comment from a number of librarians, who use indexes most and know them best. Response was gratifying. We learned we had been doing a good job of indexing in previous years, and that the revision is an improvement. Some comments were flattering—and coming from technical librarians who really have to find things in our book, the compilers of our index take that praise as from Caesar. Some helpful suggestions were included that will be incorporated in future compilations. Our index department is on the way to being expert!

"One of the worst aspects of this government control is that the modern enterpriser can find little real opportunity except in the black market, where he can reap unconscionable profits with little or no investment and generally couple his activities with tax evasion. Our government seems to be too busy promoting new social theories of how business should operate, or bringing suit against responsible companies for technical violations of incomprehensible regulations, to put a stop to black marketeers, who are destroying legitimate business in many fields and running up the true cost of living, even though it does not show on the government charts."

ROBERT E. WILSON, Chairman,
Standard Oil Company (Indiana)

Ganging up FOR MORE GALLONS PER HOUR



Elliott

Here's a line-up that assures a high score in output volume. Elliott turbines — hundreds of them — drive the main process pumps and other important equipment at a western "cat-cracker" plant. It's one more of the many cases where an important refinery standardizes on tough, trouble-free Elliott turbines for responsible tasks.

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DISPOSAL of REFINERY WASTES

L. C. BURROUGHS
Shell Oil Company, Incorporated

SINCE its inception the petroleum industry has been confronted with the problem of the proper disposal of the wastes produced from oil-refining processes. This problem has been a difficult one as refining procedures are constantly changing, necessitating development of new and better disposal methods. The oil industry has worked assiduously to keep pace with the demand for better disposal means and has spent millions of dollars on new waste-disposal equipment and on improvements to existing facilities.

Today it is becoming more and more important that strictest attention be directed to the control of waste materials discharged into rivers, lakes and other waterways. The large amount of industrial development during the war has been a factor tending to burden certain streams with wastes. Because of the scarcity of materials and urgency of installation under wartime conditions, wholly adequate waste disposal facilities were not installed in all cases. In some instances of stream pollution the condition has resulted not from negligence on the part of municipalities and industrial plants but rather from the fact that increased concentration of population and industrial activity in the particular areas have contributed small additional amounts of pollutants until the capacities of the streams for absorbing the wastes without harmful effect have been exceeded.

Today all petroleum-refinery operators are waste-disposal conscious. They are devoting more thought, time and money to keeping the waste waters free of polluting substances than ever before.

With few if any exceptions the states have had anti-pollution laws for many years. Within the past few years a number of states have passed new legislation to provide the necessary control over stream pollution. Experience has shown that state control bodies are fully cooperative with industry in helping it solve difficult waste-disposal problems. The state pollution-control agencies recognize that production of certain undesirable waste materials unavoidably accompanies many manufacturing processes and that disposal of such wastes is in many instances a very difficult problem to solve.

There has been considerable activity in Congress during the past decade regarding new anti-pollution laws. A number of bills have been introduced, but to date none has been made into law. These bills have been of two general types, the first, providing rather severe penalties for introduction of any pollutive substance into a navigable stream or its tributaries, and the second designed to aid industry in working out its pollution problems. There is no doubt that the latter type of legislation would accomplish more with less hardship on industry and municipalities than would strict penalizing laws.

ALTHOUGH this paper was not prepared as a progress report of the activities of the API Committee on Refinery Waste Disposal, the author has been active with this group for so long that the presentation has the advantage of this background. In addition his experience in plant operation gives the article the flavor of experience.

Two conditions dictate close study of the subject of waste: (1) the pressing necessity of more economical operation; (2) the fact that political bodies continue to demand more from industry in the protection of both surface and underground waters.

The paper was delivered before the regional technical meeting of the Western Petroleum Refiners' Association, Old Hotel, Lansing, Michigan, June 20, 1946.

The most recent anti-pollution bill to come before Congress is the Mansfield Bill H.R. 6024 introduced in April, 1946. This bill would (1) establish in the U. S. Public Health Service a Water Pollution Advisory Board, (2) would classify the navigable waters of the United States into districts to be known as sanitary water districts, (3) would establish standards of cleanliness and minimum treatment requirements, (4) would make loans available for installation of waste-disposal plants, and (5) would provide penalties under the law for non-conformance with regulations and purity standards established by the board. The only federal laws now on the statute books relating to control of water pollution are the Act of 1899 and the Oil Pollution Act of 1924.

Nearly 20 years ago, the American Petroleum Institute recognizing the need for better and more standardized waste-disposal practices formed the Committee on Disposal of Refinery Wastes. This committee has been very active in collecting data from refineries regarding their waste-disposal equipment and practices and has sponsored much experimental and research work to establish principles and means for satisfactory disposal of refinery wastes. This committee is the recognized authority on this subject and has extensive files on the many phases of disposal. It has published a manual presenting information to aid the refinery in handling the various wastes produced. New and up-to-date editions are published from time to time. The API Manual is in three sections, Section I—Waste Water Containing Oil, Section II—Waste Gases, Vapors, Sludges and Dusts, and Section III—Waste Waters Containing Solutes. Section II has just been revised and ex-

panded and is now ready for republication. Section III is now undergoing extensive changes and additions. The new edition should be ready in 1947.

It is impossible to present a detailed discussion of refinery-waste disposal in the short time allotted; however, it is essential to present practicable procedures for handling these wastes in order to prevent objectionable amount of pollutive substances from passing from the refinery in the waste water. This is usually the most difficult disposal problem although atmospheric pollution is also a matter to be considered.

In order to be properly conditioned for discharge into a stream, the refinery effluent must be satisfactorily free of (1) oil and sediment and (2) objectionable solutes. As a first rule to accomplish this end, everything possible should be done at the source to reduce the amount of pollutive substances entering the refinery sewers.

Removal of Substances Insoluble in Water

The universal use of water and steam in many refinery processes makes it impossible to prevent mixtures of oil and water from entering the refinery sewers. In addition, there are the inevitable spills and leakage of oil to refinery drains from various operations. It is unnecessary to enumerate the various types of oils which may find their way into refinery waste water except to state that they include straight-run and cracked distillates and residues.

The solids which enter the waste water may consist of earth particles, finely divided carbon particles, clay dust, calcium carbonate sludge from boiler-feed-water treatment, and miscellaneous other finely divided solids.

It is common practice to utilize gravitational means of separating oil and sediment from waste water. Separation is dependent upon the difference in gravity between oil and water. To accomplish the separation the mixture of oil, water and sediment is passed through one or more box-like settling basins called separators. In the separators the velocity of flow is greatly lowered thereby reducing turbulence and providing time and conditions which enable the oil to rise to the surface and the sediment to settle. Most of the separators now in use have several baffles and partitions which divide the separator into compartments. These provide retention of the major portion of the oil and sediment shortly after the waste water enters the separator. The compartments are equipped with skimming devices for removing oil from the surface of the water.

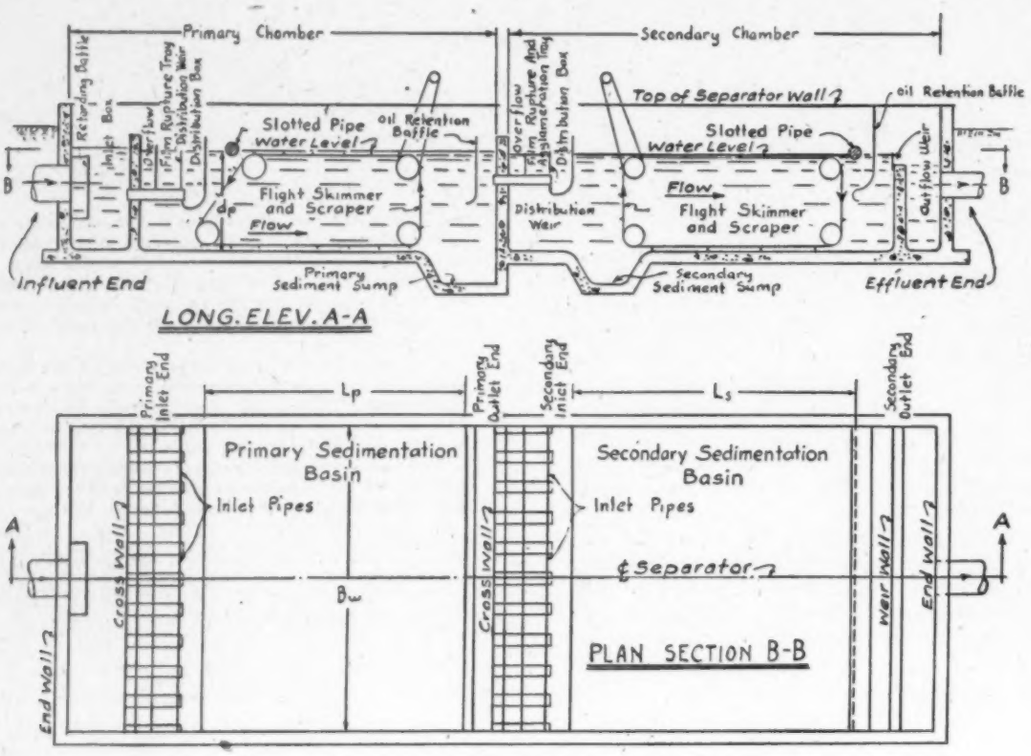
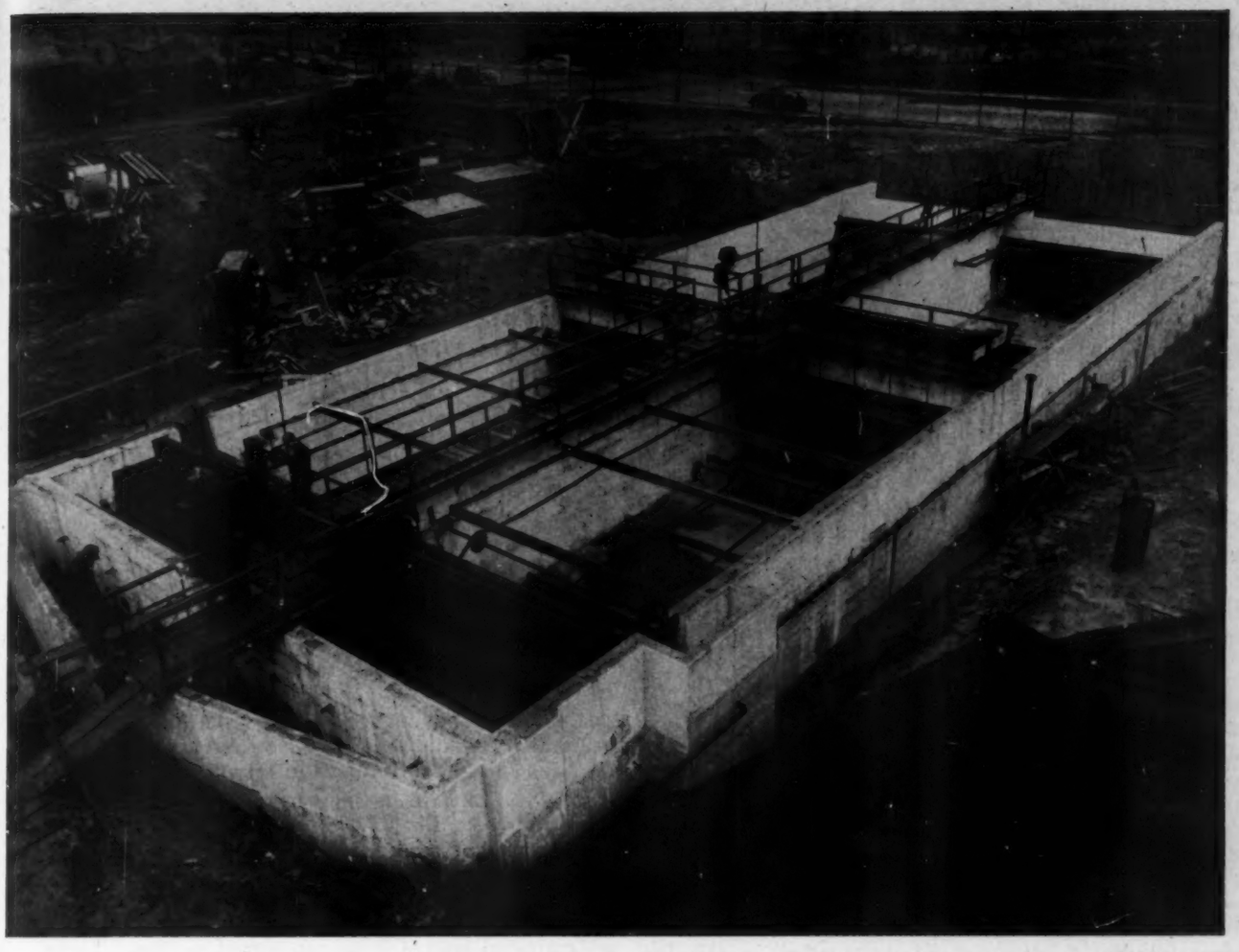


FIGURE 1

Several years ago the API Committee on Disposal of Refinery Wastes conducted a nation-wide study and survey of separator design. Many refineries were visited by the committee members in all sections of the country. It was found that there was practically no uniformity of design. Some were deep, some shallow, others were large with few compartments and many were small with many compartments. There was no agreement as to the volume of flow a separator of a certain size should be able to handle efficiently. As a result of the survey and work done by the committee members using a portable steel separator in a number of refineries on various types of waste water-oil mixtures, a separator having a number of novel features was designed. A method of calculating the proper dimensions for a separator for a particular service was devised. The calculation takes into consideration the volume, temperature and sediment con-



Showing general arrangement of the oil separator.

tent of the water to be handled and the gravity and viscosity of the oil which is to be separated.

Time does not permit a detailed description of the various features of the API separator and the method of calculating separator size. Section I of the API Waste Disposal Manual presents complete design details. Following is a brief description of the API separator:

The maximum size unit is 8 feet deep, 20 feet wide and of varying lengths. If a single unit of this size is inadequate, then one or more additional units should be installed. The separator has two compartments termed the primary and secondary chambers. The waste water enters the end of the primary chamber through a row of parallel pipes into a distribution box. From this box it flows over a weir the width of the separator and flows downward through a "film rupture" chamber and into the primary compartment proper of the separator. The "film rupture" chamber is filled with Raschig rings, lumps of coke, rocks or other agglomerate which will agitate the water-oil mixture as it passes through. This serves two major purposes (1) to shake loose particles of sand and silt clinging to the surface of oil droplets permitting these droplets to rise to the water surface in the separator and (2) to coagulate the oil droplets or in other words to take the heavy, difficultly separable oil particles into solution in the lighter oils present. The primary chamber is a rather large compartment in which the oil rises to the surface and the sediment sinks to the bottom. There are no partitions or baffles in the primary chamber except a single oil-retention baffle of streamlined shape at the outlet end. There is a power-driven flight scraper device in the primary chamber which scrapes the sediment from the bottom of the chamber into a sump at the outlet end from which it is removed with a sludge pump at regular intervals. The scraper blades operate on chains moving to the rear along the bottom and forward at the water surface, pushing the separated oil to a slotted-pipe oil skimmer at the inlet end of the separator.

From the primary chamber the water flows over a curved surface weir and gently enters the secondary chamber. This chamber has the same cross sectional shape and area as the primary chamber. It may or may not be equipped with a flight scraper and a film-rupture chamber. The secondary chamber is longer than the primary chamber in that it constitutes approximately 60 percent of the length of the separator. This chamber has no partitions or baffles except a streamlined oil-retention baffle at the outlet end. The water flows under this baffle, over a weir and is discharged from the separator. All weirs in the separator extend across the entire width to give the best possible distribution of flow, providing maximum retention time. The secondary chamber is also equipped with oil-skimming facilities.

For those who intend to install new separators this type is recommended. Many refineries have separators

which represent a considerable investment but which are not wholly satisfactory in operation. It is suggested that a study be made to determine what revisions would be necessary to bring the existing facilities more closely in line with API recommendations.

There are many factors which enter into the operation of a water-oil separator. It functions due to the difference in gravity between the oil and water and a well designed separator will perform satisfactorily provided there are no conditions prevailing which will interfere with the separation.

In studying separator operation a representative sample of the water-oil mixture entering the separator should first be taken in a glass container and allowed to stand under observation. If clean separation of oil and water does not occur in a few minutes under quiescent conditions then a study of the individual wastes which go to make up the total flow should be undertaken.

Experience has shown that as a general rule the best results are obtained when small separators are installed in the various departments of the refinery to handle the individual wastes rather than to allow them to combine before entering the separator system. The two major reasons for this arrangement are: (1) when water-oil mixtures from cracking, topping, treating and other operations are allowed to combine, there are formed, in many cases, emulsions which will not break in the separator and the efficiency of oil removal is low: and (2) frequently it is possible to return the oil recovered from the separator direct to the process from which it originated.

It is good policy to pass all waste water from the departmental separators through a large master separator before it flows from the refinery. The master separator has the difficult task of removing the last traces of oil. It serves as a safety trap in case the departmental separators are overloaded or fail for some other reason to function properly. The master separator in many cases is required to handle large volumes of surface water drainage from the refinery.

A well designed refinery has three separate sewer systems (1) oil sewers, (2) storm sewers and (3) sanitary sewers. These should be isolated from one another. Oil should never be permitted to enter the storm sewers and as much rain water as possible should be kept out of the oil sewers. Sanitary sewerage will interfere with proper functioning of oil-water separators and so should be kept out of oil sewers.

Where a large volume of water, which has been used for cooling purposes only, is discharged regularly from the refinery, it should be passed through its own separator system which can be closely designed to handle the comparatively constant flow in this type of service. If a large flow of cooling water is permitted to enter the regular separator system the problem of efficient operation is usually a difficult one and a large and expensive separator installation is required.

Assuming that a separator system of good design and of adequate capacity has been installed, there are a number of factors which, if not given proper consideration, may cause inefficient operation.

1. The separator should be given the attention it requires. Frequently separators are not kept properly free of oil and sediment and in good repair. Where this is the case, satisfactory results should not be expected.

2. Emulsions should not be discharged into the refinery sewer system, but should be broken and the oil recovered at the point of origin. If emulsions are unavoidably discharged into the sewer systems, they should be removed from the departmental separators and pumped to a suitable tank where they can be broken.

A separator has little, if any, capability in breaking emulsions and efficient oil separation with these materials present is impossible.

3. Every precaution should be taken to prevent finely divided solids from entering the waste water. Small particles of clay, coke, sand, etc., when present in an appreciable amount, tend to stabilize emulsions. These particles are frequently held in and on the surface of oil droplets thereby increasing their weight so that the rate of rise in the water is decreased appreciably or stopped. As a result the oil content of the effluent may be excessive.

4. Facilities should be provided for either removing the sediment from the waste water before it enters the separator or for keeping the chambers of the separator free of sediment. Where such provisions are not made the sediment will accumulate in the separator, reducing the cross sectional flow area and causing high flow velocity and excessive carry-through of oil and sediment.

The sediment may be removed by allowing it to settle out in a basin ahead of the separator. This basin preferably should be large so that it will require cleaning only at infrequent intervals.

A second and in most instances preferable method of handling sediment is to install a device such as a flight scraper with a sludge pump for removing sediment from the separator. With this equipment the separator can be kept continuously free of sediment.

5. Surface drainage in excess of the capacity of the separator should not be permitted to flow through the main refinery separator. If the separator has insufficient capacity for handling heavy rainfall, additional separator sections should be installed or the excess flow diverted through a large pond or basin where separation of oil and sediment can be effected. A baffle should be installed in the pond near the outlet end to retain the oil which collects on the surface.

6. The amount of alkaline chemical wastes discharged into the refinery waste waters should be kept at a minimum. Spent caustic soda and lime slurries which have been used in the treatment of various petroleum products frequently contain naphthenates, phenylates, mercaptides and other compounds which are excellent emulsion stabilizers. When introduced into the waste water, alkaline solutions of this type may seriously interfere with separation of oil and water in a separator. Numerous tests have shown that oil separation is best where the waste water is maintained neutral or slightly acidic.

Handling of Emulsions

As previously stated if emulsions are permitted to enter the refinery sewer system they will interfere with the operation of the separator which receives them. It is important then to carefully study possible sources of emulsions to determine what can be done to prevent their formation or to find a suitable method for destroying them before they are allowed to enter the sewers. Before installing plant-scale equipment for breaking an emulsion a laboratory-scale study should first be made to arrive at the most efficient procedure. Following is a brief discussion

Details of inlet end of separator. Inlet feed pipes are in lower left. Oil skimmer is slotted pipe at right of center.

of the most common emulsions encountered in a refinery.

1. *Emulsions From Traps And Separators*—Emulsions of this type usually can be broken most successfully by transferring to a tank equipped with steam coils for heating to about 180° F. After heating for several hours, at least, the emulsion is allowed to settle and the good oil which separates is reclaimed. Some refineries utilize sodium sulphide, spent caustic or weak acid to aid in breaking these emulsions. In general, heavy unbroken emulsions and bottoms are burned or are pumped to earthen pits or on plant dike walls.

2. *Emulsions From Yard Tanks*—The best procedure in most cases for handling emulsions from yard tanks is based on some method of heat treatment, either separately or in conjunction with emulsions collected from the separator system. Frequently, the emulsions cannot be combined because the stability may be so increased that it is extremely difficult to break the resulting emulsion. Tank bottoms usually are analyzed to determine whether or not the material is suitable for fuel and, if so, is burned. It may also be disposed of in earthen pits or on dike walls.

3. *Crude Oil Tank Bottoms*—Most refineries use some form of the conventional heat treatment, either alone or in combination with pressure or demulsifying agents for breaking this type of emulsion. Long-time heating and settling periods usually result in a reasonable oil recovery. In some instances the recovery of oil from this source is contracted to outsiders, thus eliminating the handling of tank bottoms in the plant.

4. *Treating Plant Emulsions*—These emulsions are of two general types, light-oil- and lube-oil-treating emulsions. Generally speaking, light-oil-treating emulsions are not a serious problem to the refiner as long as stabilizers such as blackstrap and fine earth are contained in separate recovery units or are handled separately in some other manner. Many plants have revivification units for handling spent doctor and caustic soda solutions and, therefore, do not allow materials of this type to enter the plant separator system. The addition of weak acids or caustic soda is practiced to some extent on light oil emulsions.

The most common lube-oil-treating emulsion is the so-called "white water" type resulting from soda ash or caustic soda neutralization of acid-treated lube stocks. These emulsions are usually handled by heat treatment in a tank set aside for this purpose, followed by the addition of a calcium chloride or sodium chloride solution. After separation, the oil is returned to be reprocessed and the water discharged to the sewer system. In some cases heat treatment is followed by the addition of weak acid.

The Use of Filters Following the Main Refinery Separator

Filters have been used with fair success to remove traces of oil which pass through the main refinery separator. Many types have been employed; however, probably the most successful has been that which

employs straw or hay as a filter medium. A filter used in a number of refineries consists of a rectangular wooden or concrete box located in the line or trench carrying the waste water from the main separator. The box is divided into sections by means of large mesh screens and each section is filled with hay. Small particles of oil in the water cling to the hay and the iridescence of the water surface at the waste-water outlet is decreased. To be effective, the hay must be changed at regular intervals. Usually the hay is changed once each day. Clay, sand, crushed coke and various types of cloth have been utilized for filtering the refinery waste water.

Objectionable Solutes—Their Nature and Recommended Methods For Disposal

Not many years ago it was the refiner's prime concern to maintain the refinery effluent water free of oil and sediment. Today it is equally important and in some cases more important that certain chemical wastes be kept out of the waste water. This type of material being soluble cannot be removed economically from the waste water once it has been allowed to enter it.

The large variety of chemical processes employed today in the modern refinery makes it almost impossible to enumerate all the chemical solutes which might find their way into the refinery sewers. It may be well, however, to name a few of the more common ones—organic sulfur and nitrogen compounds, naphthenic acid, phenolic compounds, and various inorganic compounds; for example, sodium chloride, aluminum chloride, hydrochloric acid, sulfuric acid, sodium sulfide, sodium hydroxide, ammonium sulfides and so on. In addition to the true solutes, there are suspensoids (suspensions of finely divided solids) and emulsoids which are present in waste waters. These materials, which may be termed as solutes, have already been discussed briefly. As in the case of objectionable true solutes, materials of this type should not be allowed to pass into refinery waste waters.

Probably the two most objectionable wastes under this classification, with which the average refinery must contend, are spent caustic soda solutions and acid sludges.

Recommended Methods For Disposing of Spent Caustic Soda Solutions

The procedure employed for disposal of spent alkaline solutions depends upon factors such as nature of solution, amount of dilution afforded by the quantity of waste water available, characteristics of the stream or body of water into which the refinery waste water is discharged, economic considerations of disposal, etc. For these reasons, the selection of a suitable method for conditioning spent caustic soda wastes is largely a problem which must be solved by the individual refinery to satisfy its particular requirements. It is frequently the case that certain refineries have idle equipment which can be utilized for disposal of caustic wastes or for regeneration of these solutions for continued use. Other refiners, not so fortunate in this respect, will find it to their advantage to employ a method of disposal which does not require a large capital expenditure for similar equipment. The following tabulation of disposal methods is not all inclusive; however, it does cover most of the procedures which are being practiced.

On the theory that an ounce of prevention is worth a pound of cure, before discussing disposal methods it may be well to consider briefly various methods for reducing the volume of spent caustic soda solutions to be disposed of.

Methods For Reducing the Volume of Spent Caustic Soda Solutions For Disposal

This subject is closely tied in with economics of refinery operation since any method for reducing the volume of spent caustic soda will also, in almost every case, reduce the amount of fresh caustic soda required. There is usually new equipment involved in order to effect savings in caustic soda consumption, with the result that these savings must be balanced against the cost of the new equipment to make the project worth while from an economic standpoint. Only a limited discussion of this subject will be given.

1. Quite frequently caustic soda solutions are disposed of before they are entirely spent. This makes for waste and increases the volume of caustic soda solution to be handled. Many refiners have found it worth while to utilize the spent caustic soda solution from doctor solution for the purpose of scrubbing hydrogen sulfide from gasolines and gases. Solutions which have lost their utility for pretreatment of gasoline ahead of doctor treatment are sometimes useful for the purpose of removing hydrogen sulfide at the topping units or elsewhere. Spent alkaline solutions, especially those used for neutralization after acid treatment of cracked distillates, are useful for breaking emulsions, particularly those of heavy cracked oils. On first hand it seems rather remarkable that it is possible to add a spent caustic solution to an oil to break an emulsion, but nevertheless in practice it is found to be feasible, particularly in breaking emulsions from cracking-plant blowoff pits. Only a limited amount should be used for this purpose, as in most cases, the chemical solution will eventually find its way into the refinery effluent.

2. Certain treatments, such as pretreatment ahead of doctor treatment, absorb mercaptans from the gasoline. Many refiners regenerate and reuse the caustic soda from these processes by heating and blowing with steam to remove the mercaptans. The gases from the regenerators have an obnoxious odor and must be disposed of by burning or introduction into a stack.

3. Proper disposal of spent doctor solution containing large percentages of acid oils, soaps, etc., is difficult. Replacement of the conventional doctor treatment with a continuous regenerative process such as the Shell Solutizer Process for removal of mercaptans will eliminate this source of caustic soda waste and at the same time give a gasoline of improved quality.

4. Many caustic soda scrubbers for removing hydrogen sulfide from gases and gasolines consist of a single stage and are low in efficiency. The gasolines or gases leaving these scrubbers will show the presence of hydrogen sulfide long before the caustic soda is entirely consumed. In most cases, a second stage will pay out in a relatively short time by making it possible to completely spend the caustic soda solution before it is discharged from the scrubber. In this operation the fresh caustic soda is always charged to the second stage and is moved into the first stage when the material in the first stage is entirely spent and removed from the scrubber. This results in a smaller volume of spent caustic to be handled.

5. Another method for reducing the volume of spent caustic soda solution resulting from hydrogen

sulfide-removing operations is to employ one of the continuous scrubbing processes such as the Shell Tri-Potassium Phosphate Process for removing hydrogen sulfide from gases and gasolines. These processes use extracting media which are continuously and almost indefinitely regenerated, yielding hydrogen sulfide of purity such that it may be sold or burned in a furnace or field flare.

6. It is the practice of some refiners to partially regenerate and reuse the caustic soda solution employed for neutralizing pressure distillate after acid treatment. The 25° Be. gravity solution is circulated in the treating process until saturated with soaps, when it is withdrawn from the system and diluted to 8 to 10° Be. gravity. The dilution causes an appreciable percentage of the soaps to precipitate from the solution. The soaps are separated from the solution which is concentrated by evaporation to 25° Be. gravity and is again used for neutralization of acid treated pressure distillate. It is sometimes possible to regenerate the solution five or six times before it becomes unsatisfactory for further use. This process effects little, if any, saving from an economic standpoint but does reduce the volume of waste caustic soda solution to be disposed of.

Disposal Methods for Waste Caustic Soda Solutions

The disposal methods outlined below are not listed in any order of preference as each has its application, depending upon the nature of the caustic soda solution and the particular waste disposal conditions prevailing at the refinery. In many instances an appreciable monetary expenditure is necessary in order to provide the equipment for proper conditioning of caustic soda wastes for disposal. It behooves the refiner to study the problem carefully before selecting a method, keeping in mind the possibilities of converting second-hand equipment for the purpose. A final decision regarding a disposal procedure should not be reached until the efficacy of the method has been proven by laboratory test. It is imperative that provisions be made for close laboratory control of the process installed.

1. *Discarding without Treatment into the Refinery Sewers*—Usually only relatively small amounts may be disposed of in this manner depending upon the pH of the refinery effluent water and the nature of the waste alkaline solution. It is not intended here to discuss the effect of the various chemical constituents in caustic soda wastes upon the taste, odor, toxicity, etc. of the waste water. Each refinery should study its waste disposal conditions to make certain that its waste water is not objectionable.

2. *Storage of Untreated Caustic Soda Wastes in Open Ponds and Sumps*—Some refiners discharge untreated caustic soda wastes into open ponds for disposal by seepage and evaporation. This method is used only as a temporary expedient, since in almost every case the volume of solution in storage builds up to a point where other means of disposal must be resorted to. These solutions usually contain phenols, nitrogen compounds, mercaptans, and other objectionable tasting and smelling compounds, and instances are on record where seepage of caustic wastes into water sands have been responsible for contamination of water supplies in the vicinity of the refinery.

3. *Neutralization with Waste Acid or Flue Gas*—Neutralization of caustic soda wasteswith waste acid, or treatment with flue gas, to release the objectionable constituents is a highly recommended procedure.

Details of sump where sludge is deposited by scrapers, showing sludge-pump suction lines.

Neutralization and blowing with air or steam at elevated temperatures usually will purify the waste caustic soda solution to an extent where it may be discharged into the refinery sewers. A brief description of a typical neutralizer follows:

The charge to the neutralizer is spent caustic soda solution from the treatment of pressure distillate stabilizer primary column bottoms. This solution contains a mixture of salts of acid oils consisting of mercaptides, naphthenates, and phenolates, but contains no sodium sulfide. The spent alkaline solution, previously diluted with 20 percent by volume of water, is charged into an 8-foot diameter by 20-foot tall vertical, cone-bottom neutralizer in batches of about 3000 gallons each. Spent weak acid, about 30 percent by weight sulfuric acid, is then added slowly, agitating with steam introduced at the cone.

The optimum pH for best removal of acid oils is the methyl orange end point. That is in the range of a pH of 4 to 5. Care is taken to avoid a more acidic solution in order to reduce corrosion. If hydrogen sulfide is evolved, steaming is continued for about 30 minutes after neutralization.

The heat of neutralization raises the temperature of the mixture to about 150° F. After settling, the bottom layer of aqueous salt solution is drawn to the sewer and the oil layer is pumped to refinery-fuel-oil storage. The neutralizer is equipped with gauge glasses which are kept clean by flushing with water through connections made to each glass.

Phenol removal in the oil layer has averaged 98.2 percent of those originally present in the spent caustic soda and spent weak acid. The nitrogen bases in the spent weak acid are also objectionable if discarded in too large a quantity with the refinery effluent. Neutralizing conditions are controlled so as to approach the maximum efficiency of phenol removal in the acid oil layer and also liberate in the oil as much of the nitrogen bases as possible. The nitrogen base removal has averaged 96.5 percent of those originally present in the spent weak acid. The separated oil layer is burned as refinery fuel. After 14 months of operation, no measurable corrosion has occurred in the neutralizer shell made of 7/16-inch tank steel.

It should be pointed out that if there are objections to releasing the aqueous layer from the neutralizer in an acid state, caustic soda solution containing

little or no objectionable constituents should be added to the acidic aqueous solution to neutralize it before it is drawn to the sewer.

Treatment of waste caustic soda solutions with flue gas to eliminate their odor and other nuisance characteristics has been successfully practiced by several refineries in this country for a number of years. A typical application of this process is described below:

The waste liquor consists of spent doctor solution and caustic soda solutions which have been used for washing various petroleum distillates. It contains caustic-soluble oils, such as phenolic compounds, naphthenic acids, and mercaptans, probably in the form of sodium salts.

The treating plant consists of a tower approximately 60 feet high and 3 feet in diameter packed with tile. Flue gas is diverted from the boiler house and introduced into the bottom of the tower with a blower, and the waste liquor is introduced within a few feet of the top. Intimate contact is obtained between the liquid and vapor phases as they run counter-current to one another, and by regulating the feed of waste liquor complete carbonation is obtained by the time it reaches the bottom. A draw-off line removes the carbonated liquor about 15 feet above the bottom of the tower, and most of the solid material settles into the bottom section and is flushed out from time to time. The carbonated liquor flows into a small auxiliary tower made of a 20-foot length of 12-inch pipe, where the oil is allowed to separate from the aqueous liquid. The separated liquids are then collected in run-down tanks. The gas passes out at the top of the tower and is discharged into the fire-box of the fume burner, where volatile material is burned.

The operation is controlled by testing the rejected solution for sulfides, and it has been found that as long as the discharged liquor reacts negatively for sulfides when tested, no trouble is experienced.

4. *Shipment of Selected Caustic Soda Waste for Processes Outside the Refinery*—In some instances certain caustic soda wastes can be shipped for use in processes outside the refinery. This usually entails careful segregation, concentration of the solution, and other handling. There is little profit, if any, in this type of business, but it serves as a means of disposal of the spent solutions.

5. *Removal of Mercaptans with Steam*—Caustic soda solutions which have been used for pre-treatment ahead of doctor treatment, or other treatments where they become contaminated with mercaptans, are frequently heated and blown with steam to remove the mercaptans before releasing the solutions to the sewer. The stripping operation generally is carried out in a small tank equipped with open and closed steam coils and a stack for carrying away the malodorous vapors. In areas where odors are particularly objectionable, the liberated mercaptans should be burned in a small specially built furnace or introduced directly into one of the refinery furnaces.

Recommended Methods for Disposing of Acid Sludges

Sludges resulting from sulfuric acid treatment of various straight-run and cracked petroleum products may be disposed of in one of the following ways:

1. *Reconversion*—The sludge may be charged to a sludge conversion contact process which will yield sulfuric acid of the desired strength for reuse, slop oil and coke. The last two named materials may be burned for disposal.

2. *Hydrolysis*—The sludge may be hydrolyzed, using water, heat and agitation. The separated oil is satisfactory for refinery fuel. This weak sulfuric acid solution may be handled as follows:

(1) Concentration or fortification is sometimes feasible. Salt and carbon content may prevent concentration to desired strengths. (2) The weak acid may be used to neutralize waste caustic soda solution as previously discussed.

3. *Burning*—Light acid sludges can be disposed of by burning in a refinery furnace. They usually can be handled satisfactorily if kept agitated until burned. A conventional oil burner using atomizing steam usually will prove adequate.

Heavy lube-oil sludges have been burned successfully by mixing them as soon as produced with an equal volume of heavy cracked fuel oil using a special mixing device.

Disposal of Spent Aluminum Chloride Catalyst

Spent aluminum chloride sludges from isomerization or other catalytic processes pose a special disposal problem. This material cannot be permitted to enter the sewer system due to the adverse effect produced by aluminum hydroxide in the waste water separators and the possibility of sewer corrosion. It is highly reactive toward water with copious liberation of hydrogen chloride.

This type of spent catalyst has been successfully disposed of by burying it with crushed limestone and covering the mixture with earth. Over a period of time it is decomposed until a mixture of coke-like material and limestone remains. No obnoxious fumes are liberated during the process and the end products appear to be unreactive to moisture and essentially neutral.

Spent liquid aluminum chloride catalyst has been disposed of satisfactorily by pressuring it to square redwood towers about 20 feet in height containing water in the bottom. Released hydrochloric acid vapor is absorbed by water which comes in at the top of the tower and percolates down over baffles. An adequate seal must be maintained at the bottom of the tower. The subsequent separation of oil and neutralization of the acidic water is accomplished outside the refinery sewer system in order to eliminate problems which would arise from aluminum hydroxide in the sewers.

Disposal of Waste Gases

There are several poisonous, irritating and malodorous waste gases and vapors produced in most refineries. These include hydrogen sulfide, sulfur dioxide, sulfur trioxide and mercaptans. Certain treating processes and the discarded chemicals from these processes release malodorous vapors.

These waste gases can usually be controlled in a satisfactory manner by confining them in a closed system and piping them to be burned in an industrial furnace, burned in a specially built waste-gas furnace, or disposed of in a stack with the flue gas from any furnace. The details of such a disposal system will vary depending upon arrangement of the processing equipment in the refinery. A capable engineer should be able to design a system to satisfy the particular need.

High- and Low-Pressure Processing Combined in McCarthy Plant

C. C. PRYOR, Associate Editor

THROUGH a combination of high- and low-pressure absorption the new plant of Glen H. McCarthy, Inc., near Winnie, Texas, is processing the gas previously flared from oil wells as well as output of gas-distillate wells in the area. Low-pressure casinghead gas, 30,000,000 cubic feet daily, comes from the nearby North and South Stowell, Fig Ridge and Fannett fields through 70 miles of gathering system. The Winnie field provides 55,000,000 cubic feet daily of gas-distillate.

As a part of the dual-purpose design several unusual features have been incorporated, including high- and low-pressure absorption and venting, three-stage compression, distillate stripping, and shell-and-tube cooling.

Three stages of compression operate ahead of processing. Casinghead gas enters the plant at 12.2 psia (Figure 1, Table 1) and is compressed to 450 psig. This gas is cooled and passes through a scrubber after each stage of compression in 10 800-horsepower angle-type compressors. Each compressor has four compression cylinders; two for first- and second-stage compression and one each for second and third stages. Although this arrangement required additional piping, it allows one or more of the compressors to be removed from service with a decrease in total capacity rather than reduction of some one stage. First-stage compression raises the pressure from —2.5 to 30 psig, second stage from 26 to 125 psig and the third stage from 121 to 450 psig.

Gas enters the last cooler at 260° F. and is cooled to 95° F. From the last compressor scrubber the gas (B) is charged to the low-pressure absorber at 105° F. and 450 psig. Both high- and low-pressure absorbers are 6 feet by 54.5 feet and have 22 trays. The large size of the individual suction and return lines of the

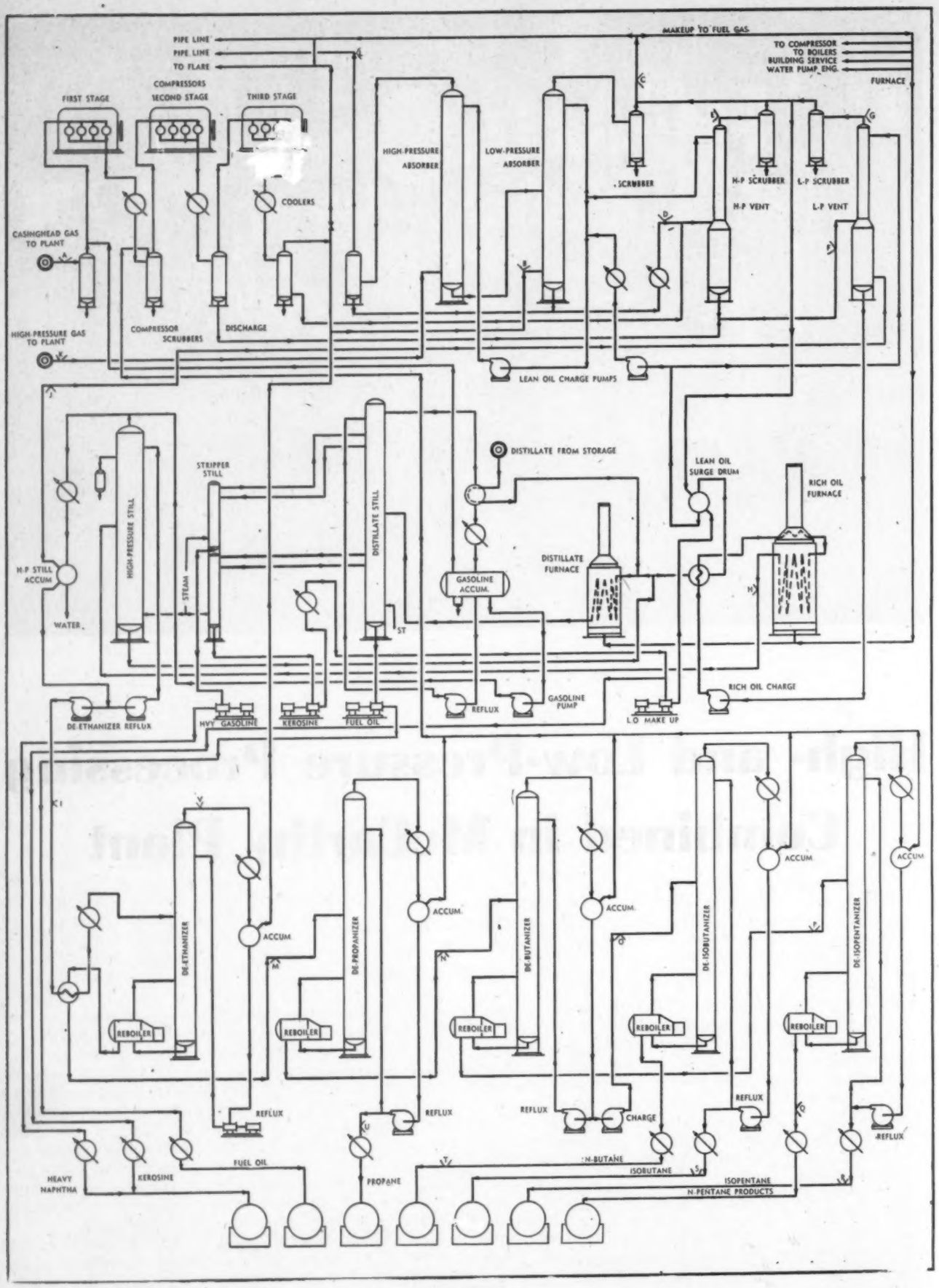


FIGURE 1

Process flow diagram, Winnie gasoline plant.

compressors required use of horizontal right-angle bends.

High Pressure Absorption

High-pressure gas to the plant from the gas-distillate field is charged to the high-pressure absorber at 105° F. and 835 psig. Dry gas overhead from the absorber passes into the 10-inch 800-pound gas transmission line at a rate of 2,175,000 cubic feet per hour. The rich oil from the bottom of the high-pressure absorber flashes as it enters the mid-section of the low-pressure absorber, releasing methane and undesirable constituents. Additional methane is released in the lower section of the tower by contact with the rich low-pressure gas. The propane and butane content, however, are increased and an economy of 40 percent less lean oil circulation is effected by the method. The low-pressure and vent gas receives a final stripping in the upper section of the low-pressure absorber by a stream of lean oil entering the top. Overhead gas, 1,188,000 cubic feet per hour, enters the 450-pound gas transmission line.

Venting and Reabsorption

Two 14-tray vent and reabsorber columns are utilized in the process for further economy of lean-oil circulation and additional butane and propane recovery. Both the high- and low-pressure vent towers have 14 trays and large-diameter lower sections and small-diameter upper sections (5 by 2.5 by 50.8 feet). Rich oil (D) from the low-pressure absorber enters the top of the lower section of the high-pressure vent tower at 95° F. and 175 psig after passing through a cooler.

Ethane and propane are flashed from the stream as

Compressor discharge scrubbers for the three stages of compression of incoming casinghead gas.

Design Material Balance—Part 1

Constituent	Gas to Compressors A		Gas to L.P. Absorber B		Total Gas From L.P. Absorber C		H.P. Vent Feed D		H.P. Vent Residue Gas E		L.P. Vent Feed F		L.P. Vent Residue Gas G		Still Feed H		Still Product Deethanizer Feed I		Still Cond. Gas to L.P. Vent J		Gas to H.P. Absorber K		Gas From H.P. Absorber L	
	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.
C1	88.20	2900	88.08	2900	93.25	2920	11.2	178	93.3	112	4.4	66	70.0	63	0.9	16	2.1	8	14.4	13	94.53	5700	96.22	5505
C2	5.00	164	5.47	181	5.25	164	3.4	54	5.0	6	3.2	48	24.5	22	3.3	55	8.5	32	32.0	29	3.24	195	2.93	167
C3	3.02	100	3.20	106	1.44	45	6.0	95	1.7	2	6.2	93	5.5	5	7.2	21	24.9	93	36.3	33	1.23	74	0.80	46
C4	2.08	69	2.03	67	0.06	2	6.4	101	.....	.....	6.7	101	.....	.....	6.8	115	26.9	101	15.5	14	0.56	34	0.05	3
C5	0.79	26	0.73	24	.....	.....	2.5	39	.....	.....	2.6	39	.....	.....	2.4	41	10.4	39	1.8	2	0.15	9	.....	.....
C6†	0.91	30	0.49	16	.....	.....	2.7	45	.....	.....	3.0	45	.....	.....	2.7	45	8.3	31	.....	.....	0.29	18	.....	.....
C7†	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.9	71	.....	.....	.....	.....	.....	.....
Lean Oil	.....	.....	.....	.....	.....	.....	67.8	1078	.....	.....	73.9	1115	.....	.....	76.7	128.8	.....	.....	.....	.....	.....	.....	.....	.....
Total	100.00	3289	100.00	3294	100.00	3131	100.00	1590	100.00	120	100.00	1507	100.00	90	100.00	1681	100.00	375	100.00	91	100.00	6030	100.00	5721
MCF/D	30,000		29,960		28,600		.....		1,092		.....		819		.....		.....		827		55,000		52,200	
LB./Hr.	64,590		63,560		53,600		215,730		2,050		220,355		1,883		252,691		24,427		3,484		105,500		95,620	
M. W.	19.6		19.3		17.1		136.0		17.1		146.0		20.9		150.0		65		37.9		17.5		16.72	
Sp. Gr. @ 60° F.							0.766				0.779				0.778		0.610							
G.P.M. @ 60° F.							563.0				565.0				646		80.5							

Design Material Balance—Part 2

Constituent	Depropanizer Feed M		Debutanizer Feed N		Deisobutanizer Feed O		Deisopentanizer Feed P		n-Pentane + Product Q		Iso-Pentane Product R		Isobutane Product S		N-Butane Product T		Propane Product U		Gas from Deethanizer V	
	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.	Mol %	Mol/ hr.
C1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8
C2	0.3	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.3	1.0	.....	31
C3	24.3	78	0.5	1	1.0	1	.....	.....	.....	.....	.....	.....	2.3	1.0	.....	.....	97.4	77.0	.....	15
Iso-C4	31.6	101	23.2	100	42.3	43	.....	.....	.....	.....	.....	.....	95.4	42.0	1.7	1.0	1.3	1.0	.....	.....
N C4			30.9		55.7	56.5	0.4	0.5	.....	.....	2.1	0.5	2.3	10	96.6	55.5	.....	.....	.....	.....
Iso-C5	12.1	39	13.5	39	1.0	1	17.0	24.0	1.3	1.5	15.8	22.5	.....	.....	1.7	1.0	.....	.....	.....	.....
N-C5			7.5				10.0	14.0	41.5	13.5	2.1	0.5	.....	.....	.....	.....	.....	.....	.....	.....
C-6	9.7	31	24.4	31	.....	.....	22.1	31	26.5	31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
C-7+	22.0	71	.....	71	.....	.....	50.5	71	60.7	71	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total	100.00	321	100.00	242	100.00	101.5	100.00	140.5	100.00	117.0	100.00	23.5	100.00	44	100.00	57.5	100.00	79.0	.....	54
MCF/D	.....		.....		.....		.....		.....		.....		.....		.....		.....			491
LB./HR.	22,709		19,231		5,876		13,355		11,670		1,685		2,538		3,349		3,476			1,718
M. W.	71		79		57.7		95		100		71.7		57.7		58.1		43.9			32
Specific Gravity @ 60° F.	0.628		0.655		0.572		0.701		0.715		0.622		0.565		0.579		0.506			....
G.P.M. @ 60° F.	72.4		58.7		20.6		38.1		32.7		5.4		9.0		11.6		13.7			....

Rich-oil pumps are vertical, electrically driven. All pumps are in open area in center of processing equipment.

it enters. The flashed gas is finally stripped of butane and propane by lean oil in the upper part of the tower. Bottoms of the high-pressure vent (563 gallons per minute, 0.766 specific gravity), (F) are charged to the low-pressure vent tower at the top of the large section at 95° F. and 50 psig. A flash takes place at the entrance to the vent tower and the rich oil absorbs vent ethane and propane from the rich low-pressure vent gas (J) from the high-pressure still accumulator drum charged at the middle of the lower section of the vent tower. The flashed gas is stripped of butane and propane by a lean-oil stream entering the top of upper section in the tower. Overhead gases (E and G) from the two vent towers (1,911,000 cubic feet daily) are passed through scrubbers to the plant fuel-gas system.

Heating and Stripping

Bottoms from the low-pressure vent tower (646 gallons per minute, 778 specific gravity) are picked up by a rich-oil charge pump, heated by the hot lean oil from the high-pressure still in an exchanger to 377° F. and charged to the rich-oil furnace. The rich-oil furnace, vertical gas-fired, develops 14,100,000 Btu per hour to heat the rich oil (H) to 460° F. Raw gasoline is stripped from the rich oil in the 20-tray high-pressure still, 7 by 49.5 feet, operated at 125 psig and 450° F., and the hot lean oil cooled and pumped to the surge tank.

Condensate from the high-pressure wells, approximately 1300 barrels per day, after stage flashing, is heated in a second vertical-type, gas-fired distillate furnace (see Figure 1) and charged to the distillate still, which is 4 by 65 feet, with 28 trays and operates at 8 psig and 455° F. The furnace develops 3,850,000

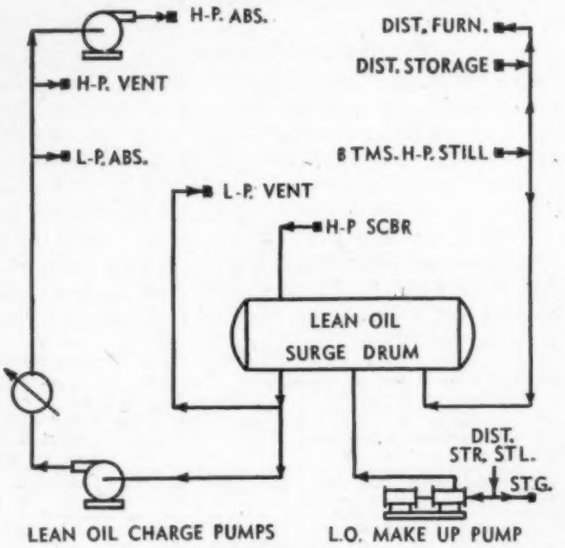


FIGURE 2

Btu per hour to heat the distillate from 225 to 455° F. Overhead product, gasoline, is combined with the overhead stream of the high-pressure still. A stripper still produces heavy gasoline (4 trays operating at 7

TABLE 2

Pump Schedule

No.	Type	Service	Capacity G.P.M. Maximum	Discharge Pressure Psig	Diff. Pressure Psig	Pumping Temp. °F.	Driven	Driven Bhp.
3	Centrifugal	L. P. Lean Oil	276	521	446	100	Electric	125
2	Centrifugal	H. P. Lean Oil Booster	322	881	360	100	Electric	125
3	Centrifugal	Rich Oil Charge	364	257	204.3	95	Electric	100
2	Centrifugal	Still Reflux	315	147	29.6	95	Electric	10
2	Reciprocating	Deethanizer Reflux	52	521	34.2	95	Steam	....
2	Centrifugal	Depropanize Reflux	100	270	33	115	Electric	5
2	Centrifugal	Debut. Reflux	61	117	34.7	120	Electric	5
2	Centrifugal	Deisobut. Reflux	139	134	41.7	120	Electric	7.5
2	Centrifugal	Deisopent. Reflux	106	86	48.6	160	Electric	7.5
2	Centrifugal	Cvert. Hydro Press Deethan-Feed	71.5	554	436.6	95	Electric	40
2	Centrifugal	Deisbut. Feed	24	130	62.7	120	Electric	7.5
1	Reciprocating	Lean Oil Makeup	5	138	134.6	150	Steam	....
2	Centrifugal	Light Prod. Shipping	100	199.7	50	90	Electric	10
2	Centrifugal	Circ. Water	7,000	62	62	86	Gas PUG-8 Engine	370
1	Centrifugal	Hvy. Prod. Shipping	55	76	76	90	Electric	10
3	Centrifugal	Jacket Water	3,700	39	34.7	150	Electric	100
1	Reciprocating	Water Trap Pump	200	71	74	90	Steam	....
2	Turbine	Water Well Pump	550	43.3	43.3	75	Gas Engine	42
2	Reciprocating	Boiler Feed	70	196.5	192	212	Steam	....
2	Reciprocating	Steam Cond.	35	14.6	11.7	212	Steam	....
2	Centrifugal	Distillate Tower Chg	46	64.8	63.5	65	Electric	5
2	Reciprocating	Gas-Oil Prod. Pump	6.5	30.4	21.3	435	Steam	....
1	Reciprocating	Kerosine Prod	14	30.4	22.5	385	Steam	....
2	Reciprocating	Naphtha Prod	16	50	38.8	315	Steam	....
3	Centrifugal	Dist. Tower Reflux	....	44.5	39	100	Electric	3
2	Centrifugal	Gasoline	22	150	140	100	Electric	7.5

psig and 315° F.) and kerosine (4 trays operating at 7.5 psig and 315° F.) by side-stream stripping. Fuel-oil bottoms of the distillate still are pumped to storage.

Lean oil, after stripping in the high-pressure still, flows under pressure to the lean-oil surge tank through a series of heat exchangers heating the charge to the rich-oil furnace. A side-stream connection from the line to the exchangers permits 1.4 gallons per minute of the hot lean oil to enter the distillate line from storage to the distillate furnace. The hot distillate is then charged to the distillate still and steam stripped with 170 psig steam at 425° F. The kerosine side-stream stripper still supplies lean oil through the lean-oil makeup pump to the surge or makeup tank. This continuous system maintains the purity of the oil in use for efficient absorption and supplies makeup necessary from the charge to plant.

Lean oil flows from the makeup tank under pressure to the low-pressure vent tower and to the suction of the low-pressure absorber and high-pressure vent tower due to the pressure of gas from the high-pressure scrubber. The stream from the low-pressure charge pump passes through a cooler to the low-pressure absorber, the high-pressure vent tower, and the high-pressure absorber pump at 450 psig. The high-pressure absorber pump boosts the pressure to 825 psig.

Deethanizing

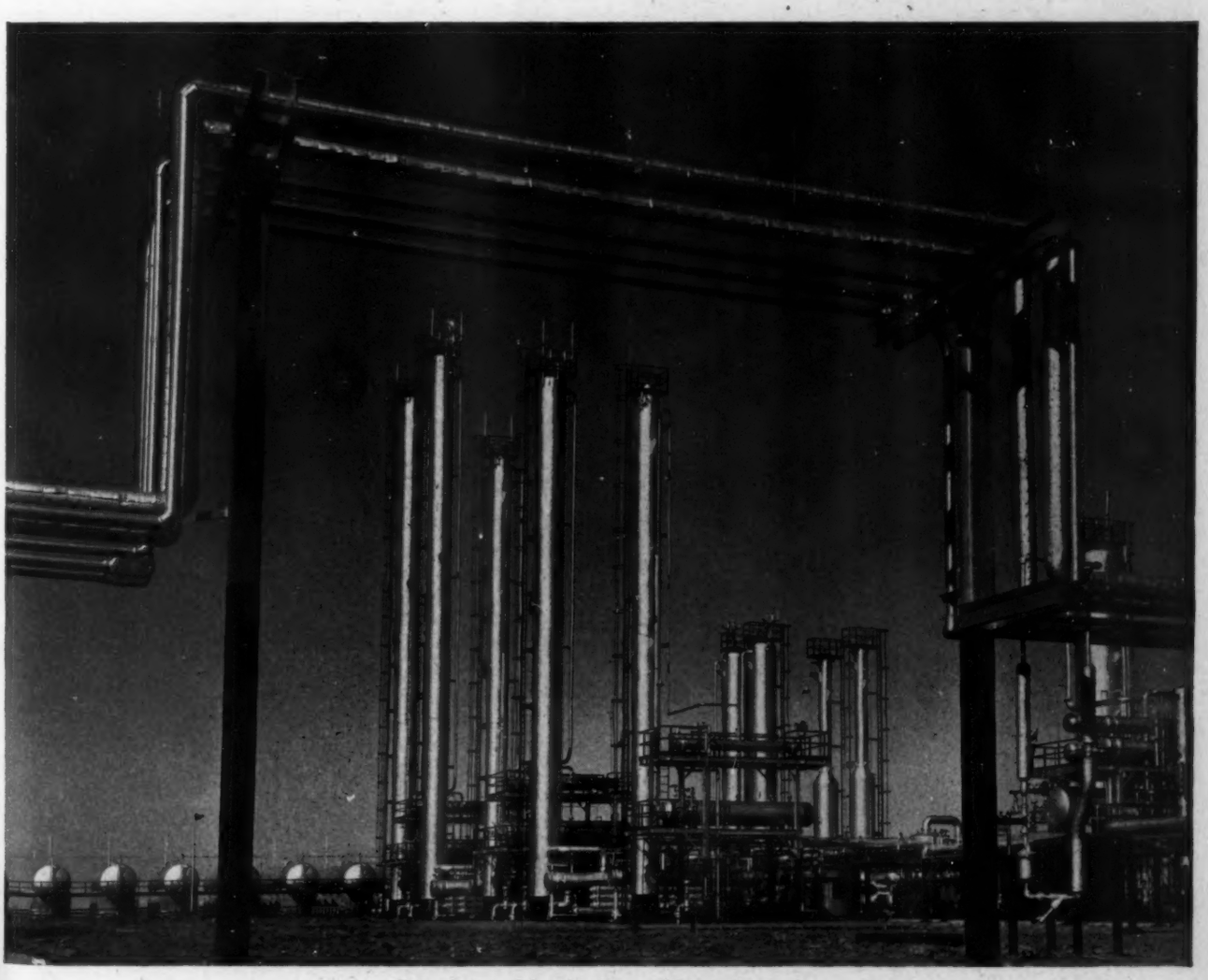
Raw gasoline overhead, 85,791 pounds per hour, from the high-pressure still at 220° F. and raw gasoline from the distillate still, 6332 pounds per hour (18 gallons per minute) 0.705 specific gravity, combine in one stream and pass through a condenser to the high-pressure still accumulator at 120 psig and 95° F.

The charge (I), 24,427 pounds per hour (80.5 gallons per minute), 0.610 specific gravity, to the deethanizer operated at 495 psig and 310° F. is picked up from the accumulator drum by two 14-stage centrifugal pumps operating at 550 psig, heated by exchanging with the reboiler bottoms of the tower and a steam exchanger to 250° F. before entering the tower.

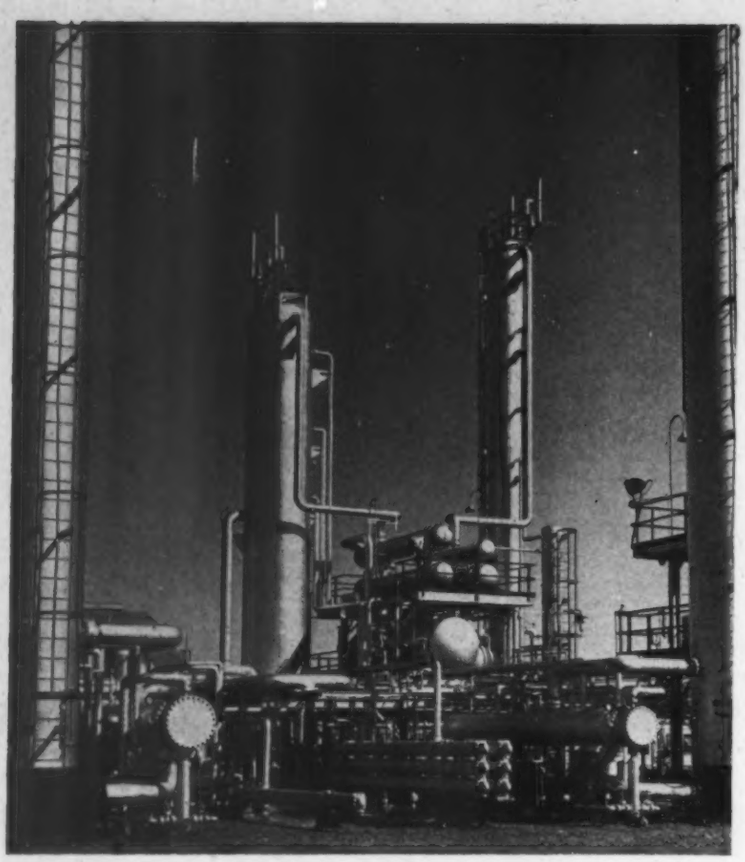
The deethanized product (M), 0.628 specific gravity, 72.4 gallons per minute, from the bottom of the tower's reboiler at 320° F. is charged through the feed exchanger to the depropanizer at 190° F. Vapor from the deethanizer accumulator drum is fed to the low-pressure absorber gas-charge line. Reflux ratio of the deethanizer is 7:1. The tower is 3.5 by 69.5 feet with 30 trays.

Fractionation

Commercial propane (U) is produced overhead by the depropanizer operating at 245 psig and 300° F. and a reflux ratio of 5:1. Bottoms (N) from the de-



General view of fractionation and processing area.



Deethanizer, rich-oil and distillate stills, side-stream stripper and depropanizer in processing area of plant.

propanizer, 4.5 by 86 feet, 40 trays, are charged to the debutanizer and butanes (O) produced overhead with a reflux ratio of 2.5:1. The butanes are charged to the deisobutanizer, which is 3.5 by 80.8 feet with 40 trays, for further splitting into isobutane overhead (S), reflux ratio 12:1, and normal butane (T) as a bottom product.

The tower operates at 290° F. and 75 psig. Overhead product of the debutanizer is fed to the deisopentanizer for splitting into isopentane (R) as overhead product, reflux ratio 15:1, and normal pentane plus (Q) as bottom product. The deisopentanizer has 60 trays, is 4.5 by 114 feet, and operates at 280° F. and 45 psig. Vapors from the depropanizer, debutanizer, deisobutanizer, and the deisopentanizer accumulator drums are charged to the second compressor discharge scrubber. Stabilized gasoline can be produced as a bottom product of the debutanizer tower.

Product Storage

Products are stored at the plant in 15 60- by 10-foot diameter horizontal tanks, 35,000 gallons capacity per tank, for liquid products and 2 5000-barrel bolted tanks for distillate. A 25- by 10-foot diameter underground storage tank is used for lubricating-oil storage.

Loading racks for tank cars are on a double track and will handle 16 cars. Two truck loading racks have been provided. Vapor return lines permit safe and economical loading of high-vapor-pressure products.

Steam Requirements

Either of the two gas-fired bent tube boilers are capable of supplying total requirements of 30,000 pounds per hour of steam at 175 psig and 379° F. Turbine-driven induced-draft fans are employed to permit use of minimum height stacks.

All steam condensate of good quality is returned to the boilers. Steam condensate from the high-pressure still is separated and returned to a horizontal skimming tank and then combined with trap condensate. The condensate is deaerated and heated by contact with exhaust steam and boiler-feed makeup in a strip tower. Boiler feedwater is supplied by two steam-driven reciprocating pumps after the water passes through a hot lime process for softening.

Shell-and-Tube Coolers

All water-cooled units of the plant are of shell-and-tube construction. This practice permits a simpler piping layout and cooling-tower construction of four cells of induced-draft design. Each cell has a 60-horsepower motor-driven fan. Also, operating costs are reduced as shell-and-tube units are easily maintained. The tower is capable of 5000 gallons per minute from 120° to 100° with 80° F. wet-bulb temperature and negligible wind velocity.

Circulating cooling water for the coolers and condensers is treated by the latest methods and includes continuous chlorination for algae formation, and chemical treatment of makeup water for pH control and scale preventions.

Two off-site wells, approximately 180 feet in depth, supply the plant with water. Each well is capable of supplying normal plant requirements. Turbine-type pumps, driven by gas-gasoline engines, are employed on each well.

Electric power for the plant is supplied by a utility company 33,000-volt feeder line. Voltage is reduced to 2300 and 440 for use in the plant. The 2300-volt motor lines are run in an underground cable system and the 440-volt lines in overhead conduits. Independent circuits are provided for all spare electrically-driven equipment and an underground grid is used for grounding all equipment.

When first planned the plant was expected to contribute materially to the output of aviation motor fuels and other war requirements in petroleum. In the transition from wartime to peacetime economy construction was affected by difficulties in material deliveries as well as design changes to allow flexibility of operation in keeping with changing demand. The plant produces propane (50 percent recovery) natural gasoline, motor fuel, normal and isobutanes (96 percent total recovery) isopentane, kerosine and fuel oil, total all products 3200 barrels daily. Propanes and pentanes have product purity of 95 percent. At present the deisopentanizer is not being operated.

Dry gas is piped to Beaumont, Orange and Port Arthur for domestic and industrial consumption.

The plant was designed and built by Stone and Webster Engineering Corporation. Personnel of the McCarthy organization who participated in the project are: D. C. Harman, superintendent of production; J. J. Sappington, plant superintendent; Frank Bewley, production engineer, and Leon Dorsey, process engineer.

Desalting of Petroleum

With Fiberglas Packing

C. G. KIRKBRIDE, Professor of Chemical Engineering

A. & M. College of Texas

A PILOT-PLANT investigation was carried out at the A. & M. College of Texas to determine the feasibility of using beds of relatively fine glass fibers for desalting of petroleum. This work was extended by a pilot-plant investigation at the Whiting, Indiana, refinery of Standard Oil Company (Indiana). The process consists briefly of (1) washing the crude oil with water at a minimum temperature of 250° F., (2) passing the oil and water through beds of glass fibers averaging 0.00028 inches in diameter to coalesce the emulsified water, and (3) separating the desalted oil from the wash water. The wash water may be recycled in most cases to conserve heat and fresh water. Only sufficient fresh water is needed, if recycling is done, to maintain the salt content of the wash water at a maximum of 3 percent by weight.

Life of the Fiberglas packing is in excess of two months. It has been found that salt content can be reduced to less than 10 pounds per 1000 barrels of oil by proper control of temperature, superficial velocity and glass surface in the beds. In general the temperature should be at least 275° F. for best results. A superficial velocity of 1.0 foot per minute seems feasible for commercial units provided the temperature is maintained sufficiently high to give a pressure drop of not over 5 pounds per square inch through a single bed of Fiberglas packing. A total of 5 individually supported beds each of 2 inches depth at 6.5 pounds per cubic foot density appears to be a reasonable basis for commercial designs to provide desalting to not over 10 pounds per 1000 barrels.

The process is effective and appears to be quite attractive from an economic standpoint for commercial application.

Much of this article is a reproduction of the paper, "Desalting of Petroleum by Use of Fiberglas Packing," by T. A. Burtis and C. G. Kirkbride, which was presented April 2, 1946, at the meeting of the American Institute of Chemical Engineers, Houston, Texas, and published in the Transactions of A.I.Ch.E., June 25, 1946.

THE following presentation first describes in a general way the desalting process and the pilot plants used in the experimental work. Then the experimental results are given which include correlations on the effects of velocity, temperature, water-to-oil ratio, salt content of the wash water, Fiberglas-bed density, settling time required, Fiberglas-packing life and mixing. Finally the commercial application of the process is treated.

Description of the Pilot Plants

Figure 1 presents a simplified flow diagram of the pilot plant located at the A. & M. College of Texas, which will be referred to as pilot plant A. The pilot plant of Standard Oil Company (Indiana), which will be referred to as pilot plant B, was quite similar, however there was an arrangement whereby the wash water and crude oil could be mixed either by expansion through a globe valve or in the gear-type oil-charge pump. The globe valve was located on the discharge side of the pump between the pump and heater.

A detailed description of the size of each item of equipment in pilot plant A has been presented,[1] so will not be repeated here. The size of pilot plant B was about the same except that the contactor had provision for five individually supported beds of Fiberglas packing each of two inches depth. Also there was an arrangement so that either or both of the two upper beds could be by-passed if desired.

The operation of each pilot plant was likewise similar. The source of crude oil for pilot plant A was the drums in which it was received. The source of the crude oil for pilot plant B was a pipe line which was used to charge one of the commercial units in the refinery. In each pilot plant the crude oil was drawn into the unit by the charge pump and mixed with wash water. The mixture of oil and water was then passed through a heater to the contactor which contained the Fiberglas beds. The glass fibers caused agglomeration of the dispersed aqueous phase of the emulsion into droplets large enough to settle from the continuous oil phase.

The contactor effluent, a heterogeneous mixture of oil and water, passed to a horizontal settler in which phase separation took place. Desalted oil was withdrawn from the top of the vessel through a cooler. In the case of pilot plant A a slight amount of water was rejected to the sewer and the remainder recycled to the crude-oil pump. Only sufficient fresh water was added to control the salt content of the wash water which, of course, required that the same amount of water be rejected to the sewer. Generally, pilot plant B was operated with no recycling of wash water, but on a few occasions the wash water was recycled. The pH of the wash water was controlled at 7 to 8 in the normal operation of pilot plant A but no effort was made to control the pH of the wash water in the operation of pilot plant B.

Experimental Results

In the earlier experimental work on pilot plant A, five different crude oils were used in the investigations. Pertinent data on each of these crude oils are given in Table 1.

The work on pilot plant B was done primarily with a West Texas crude although during a few short periods a mixture of crudes (referred to as B crude) was used. The salt content of this West Texas crude

TABLE 1
Crude Oils Used in Pilot Plant Work

CRUDE	Supplier	Degrees A.P.I.	Viscosity SSU	Average Salt Lbs/M Bbls.
Hastings	Pan-American	31.3	50 at 100 °F.	65
Panhandle	Humble	33.4	66 at 100 °F.	50
West Texas (Sour)	Magnolia	34.4	45.2 at 128 °F.	29
South Louisiana	Texas	34.3	41.2 at 128 °F.	122
Hockley (West Texas)	Texas	29.2	39.6 at 128 °F.	272

ranged from 144 to 290 pounds per 1000 barrels. Its gravity was about 31.5° API and its viscosity was 38.1 SSU at 128° F.

The salt content of B crude ranged from 38 to 83.5 pounds per 1000 barrels. Since it was processed over such limited periods, little further consideration will be given to it.

The type Fiberglas packing used in all the experimental work was fibers which have an average diameter of 0.00028-inch, an average length of 15 inches and an average surface area of 1079 square feet per pound.

In the investigation of pilot plant A, the Fiberglas packing was always compressed to some pre-determined density, usually 13 pounds per cubic foot. The range of density covered was 9 to 15 pounds per cubic foot. Above about 15 pounds per cubic foot the glass fibers are injured due to mechanical breakage. Even so at this density, it is apparent that there was approximately 90 percent void space in the bed since glass has a density of 159 pounds per cubic foot.

In the investigation on pilot plant B the beds were compressed to 13 pounds per cubic foot in the first few runs but in the last run pre-compression was not done.

Most of the runs on pilot plant A were made with three individually supported beds of 13 pounds per cubic foot density with a total depth of 5 inches. In all but the last run on pilot plant B, 5 individually supported beds each of 2 inches depth were used.

The method of analysis used was the same in each investigation. This method is based on determining only the chloride ion concentration expressed as NaCl. Since the method has been described briefly,[1] it will not be discussed further at this time.

BS and W determinations were made only on random samples in the investigations on pilot plant A. It was found in all cases in which Fiberglas packing was used that the BS and W of the desalted oil after proper settling was less than 0.2 percent. Actually it was necessary to centrifuge at 30,000 revolutions per minute to detect as much as 0.1 percent water. Hence, BS and W determinations were not made regularly.

In the investigation on pilot plant B, BS and W determinations were made regularly inasmuch as rather high values were obtained at times.

The experimental work on pilot plant A was directed primarily toward the determination of the effect on desalting of velocity, temperature, wash-water-to-oil ratio, total depth of the Fiberglas packing (at 13 pounds per cubic foot density), density of the Fiberglas packing, and salt concentration of the wash water. Detailed data from this work have been presented previously[1] and will not be reproduced here.

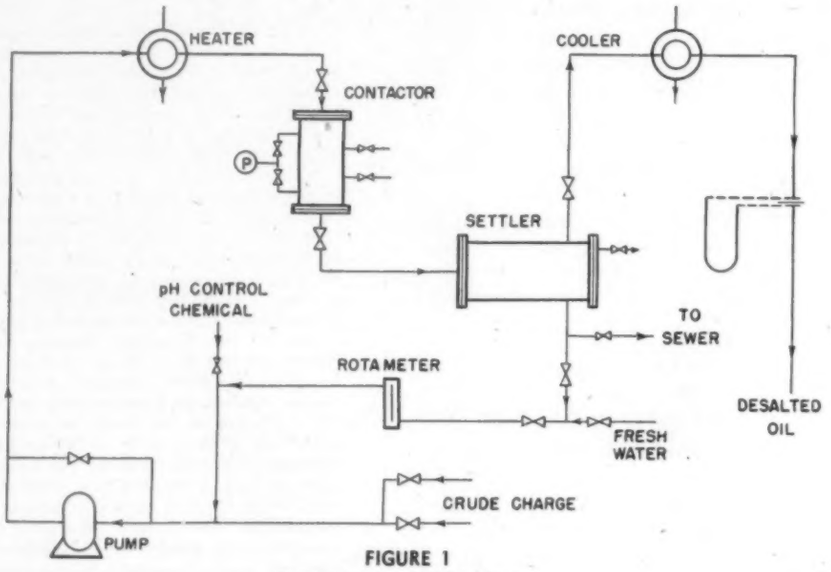


FIGURE 1
Flow diagram of Pilot Plant A.

The work on pilot plant B was directed chiefly toward the determination of the life of Fiberglas packing. Even so pertinent information was obtained on whether or not pre-compression of the packing is desirable as well as on the method of mixing and the wash-water-to-oil ratio. Five different runs were made during a period of about 100 days. The first three runs were short since they were devoted to developing operating technique that could not be studied on pilot plant A. The fourth run extended over a period of 57 days and was arbitrarily terminated. The last run was of 12 days duration and was also terminated arbitrarily. Data for Runs 4 and 5 are presented in Tables 2 and 3 respectively. Samples were taken for analyses every 6 hours but only one set of data each day is presented. The data on the 5:00 p.m. sample were arbitrarily chosen except in a few cases when changes in conditions were made so near the time of sampling that steady state had not been reached. In these cases the sample taken just prior to the change in conditions or the sample taken about 6 hours after the change was selected.

Superficial Velocity

Superficial velocity as used in this paper is the linear velocity in feet per minute at which the *oil only* would pass through the empty contactor. The asso-

TABLE 2

Data in Run No. 4 on Pilot Plant B

DAY	Type Mixer	Crude	Water to Oil Ratio Vol/Vol	Velocity Ft/Min	Temperature °F.		Contactor Pressure psig		Crude Charge		Desalted Oil		Settled Water	
					Contactor Inlet	Settler Outlet	Inlet	Outlet	Salt Lbs/M Bbl	B S & W	Salt Lbs/M Bbl	B S & W	Salt %	pH
2/20	GV[1]	WT[2]	0.25	0.50	300	197	180	145	243	0.5	1.3	0.7	0.53	....
2/21	GV	WT	0.25	0.50	300	209	180	145	246	0.7	7.5	2.3	0.76	....
2/22	GV	WT	0.25	0.50	300	192	190	145	249	0.7	6.9	0.6	0.24	....
2/23	GV	WT	0.25	0.50	300	213	191	150	235	0.9	0.7	1.0	0.53	....
2/24	GV	WT	0.25	0.50	300	212	185	150	272	0.9	16.6	1.3	0.88	....
2/25	GV	WT	0.25	0.50	300	212	182	150	288	1.0	0.7	2.1	0.59	....
2/26	GV	WT	0.25	0.50	300	218	185	152	269	1.0	2.0	0.9	0.55	....
2/27	GV	WT	0.25	0.50	300	216	180	150	249	1.0	18.6	1.2	0.44	6.2
2/28	GV	WT	0.25	0.50	300	220	200	150[4]	250	0.6	17.9	1.4	0.40	5.8
3/1	GV	WT	0.25	0.50	300	224	210	150[4]	258	0.6	10.2	1.3	0.45	....
3/2	GV	WT	0.25	0.50	300	234	190	150	197	0.9	15.2	2.8	0.46	....
3/3	GV	WT	0.25	0.50	300	231	175	150	214	0.7	18.6	1.1	0.45	....
3/4	P[2]	WT	0.167	0.75	300	182	160	150	259	1.0	0.7	0.6	0.45	....
3/5	P	WT	0.167	0.75	300	228	180	150	243	0.6	9.6	0.8	0.45	....
3/6	P	WT	0.167	0.75	300	234	180	152	214	0.4	11.0	5.0	0.23	....
3/7	P	WT	0.25	0.50	300	228	170	150	208	0.8	14.4	1.1	0.32	6.1
3/8	P	WT	0.25	0.50	300	210	160	150	232	0.8	7.6	1.4	0.30	6.8
3/9	P	WT	0.25	0.50	300	210	165	150	235	0.9	8.3	1.4	0.27	6.7
3/10	P	WT	0.25	0.50	300	209	165	150	242	0.9	8.3	1.4	0.27	6.0
3/11	P	WT	0.25	0.50	300	210	165	155	253	0.7	8.3	1.1	0.25	6.1
3/12	P	WT	0.25	0.50	300	217	165	160	246	0.7	11.0	1.3	0.30	6.1
3/13	P	WT	0.25	0.50	300	218	160	153	248	0.7	11.7	1.8	0.30	7.0
3/14	P	WT	0.25	0.50	300	211	162	155	248	0.5	11.0	1.4	0.30	6.4
3/15	P	WT	0.25	0.50	300	214	160	155	268	0.8	10.2	1.8	0.30	7.2
3/16	P	WT	0.25	0.50	300	212	158	155	284	0.6	12.4	1.6	0.31	7.0
3/17	P	WT	0.25	0.50	300	214	158	153	242	0.8	11.0	1.4	0.31	7.0
3/18	P	WT	0.25	0.50	300	212	154	150	281	1.0	13.1	1.7	0.31	7.0
3/19	P	WT	0.25	0.50	300	218	156	153	256	0.6	11.7	1.2	0.34	6.5
3/20	P	WT	0.125	1.00	300	212	160	156	227	1.0	13.8	2.0	0.28	6.1
3/21	P	WT	0.125	1.00	300	230	185	175	207	0.6	8.3	1.0	0.48	7.0
3/22	P	WT	0.125	1.00	300	240	185	175	218	0.6	15.8	3.0	0.53	6.6
3/23	P	WT	0.125	1.00	300	243	185	175	203	0.7	9.7	1.2	0.52	6.8
3/24	P	WT	0.125	1.00	300	245	185	175	194	0.6	16.6	2.0	0.48	6.4
3/25	P	WT	0.125	1.00	300	240	180	175	191	0.6	....	....	0.43	5.9
3/26	P	WT	0.125	1.00	300	250	180	175	183	0.8	20.7	2.3	0.43	6.1
3/27	P	WT	0.125	1.00	300	252	180	175	179	0.6	83.4[5]	4.6	0.43	5.6
3/28	P	WT	0.125	1.00	300	250	180	175	201	0.6	88.3[6]	5.4	0.71	5.2
3/29	P	WT	0.125	1.00	300	252	180	175	207	0.6	24.1[7]	3.4	0.65	5.2
3/30	P	WT	0.125	1.00	300	250	180	175	210	0.6	11.7	1.8	0.51	6.2
3/31	P	WT	0.125	1.00	300	250	180	175	217	0.6	8.3	1.2	0.50	5.1
4/1	P	WT	0.125	1.00	300	246	182	178	204	0.6	8.3	4.2	0.53	5.8
4/2	P	WT	0.061	1.00	300	246	180	178	207	0.8	98.0	6.2	0.55	5.8
4/3	P	WT	0.061	1.00	300	248	180	178	255	0.8	69.0	5.0	0.46	4.3
4/4	P	WT	0.125	1.00	300	253	180	178	241	0.8	49.0	2.8	0.54	5.7
4/5	P	WT	0.2	1.00	300	256	180	178	268	0.8	7.6	1.0	0.43	5.9
4/6	P	B	0.2	1.00	300	258	180	176	38	0.6	12.4	13.2[8]	0.07	....
4/7	P	B	0.2	1.00	300	254	182	179	38	0.7	9.7	10.0[8]	0.06	....
4/8	P	B	0.2	1.00	300	255	180	177	83.4	0.7	13.1	10.4[8]	0.07	....
4/9	P	WT	0.2	1.00	300	246	178	175	260	0.8	9.0	1.9	0.43	....
4/10	P	WT	0.192[9]	1.00	300	252	183	182	255	0.8	18.0	1.5	0.48	6.4
4/11	P	WT	0.192[9]	1.00	300	252	180	178	226	0.9	68.0	3.8	0.50	6.5
4/12	P	WT	0.125	1.00	300	249	180	179	262	0.9	11.7	0.6	0.48	6.2
4/13	P	WT	0.08	1.00	300	246	180	177	147	0.4	52.4	4.6	0.41	6.4
4/14	P	WT	0.08	1.00	300	245	180	177	160	0.6	122.1	5.6	0.39	7.0
4/15	P	WT	0.125	1.00	300	250	180	177	190	0.6	10.3	1.1	0.46	6.2
4/16	P	WT	0.125[10]	1.00[10]	300[10]	...	...	...	...	....	9.9[10]	0.9[10]	....	....
4/17														

[1] 35-pound pressure drop through a globe valve.
[2] Wash water admitted to suction of the gear type pump.
[3] West Texas.
[4] These readings are probably high. A new gauge showed pressure drop of 40 psi on 3/2.
[5] 100 percent recirculation of water separated in settler from 10 a.m. 3/27, to 12 noon 3/28, to build up solids concentration in wash water.
[6] Wash water composed of 50 percent recycle water and 50 percent fresh water from 12 noon 3/28, to 3 p.m. 3/29.
[7] Wash water composed of 100 percent fresh water beginning 3 p.m. 3/29.
[8] A water to oil ration of 0.2 was found to be too high for B crude.
[9] Wash water composed of 20 percent recycle water and 80 percent fresh water.
[10] Average over last 56 hours of operation. Run was terminated voluntarily.

TABLE 3

Data in Run No. 5 on Pilot Plant B

DAY	Type Mixer	Crude	Water to Oil Ratio Vol/Vol	Velocity Ft/Min	Temperature °F.		Contactor Pressure psig		Crude Charge		Desalted Oil		Settled Water	
					Contactor Inlet	Settler Outlet	Inlet	Outlet	Salt Lbs/M Bbl	B S & W	Salt Lbs/M Bbl	B S & W	Salt %	pH
4/19	P*	WT	0.125	1.00	300	242	195	177	259	0.7	2.0	0.9	0.55	6.2
4/20	P	WT	0.125	1.00	300	240	210	177	170	0.6	4.8	0.9	0.71	6.4
4/21	P	WT	0.125	1.00	300	244	215	176	139	0.6	8.3	1.0	0.49	6.3
4/22	P	WT	0.125	1.00	300	245	217	175	179	0.6	4.1	0.7	0.48	6.3
4/23	P	WT	0.125	1.00	300	245	218	173	241	0.6	3.4	0.9	0.38	6.2
4/24	P	WT	0.125	1.00	300	248	210	175	285	0.6	5.5	1.0	0.48	6.4
4/25	GV†	WT	0.125	1.00	300	246	215	175	265	0.8	16.0	1.9	0.45	6.3
4/26	GV	WT	0.125	1.00	300	249	190	177	265	0.7	25.5	2.6	0.51	6.2
4/27	GV	WT	0.125	1.00	300	248	184	175	194	0.9	20.7	1.4	0.51	6.8
4/28	GV	WT	0.125	1.00	300	249	183	175	144	0.8	22.7	1.7	0.51	6.6
4/29	P	WT	0.125	1.00	300	250	185	178	213	0.9	8.3	0.9	0.48	6.6
4/30	P	WT	0.125	1.00	300	248	185	178	230	1.0	9.7	0.4	0.49	6.0

* Wash water admitted to suction of crude pump. † Wash water admitted to discharge of pump and mixing obtained by expanding through a glove valve with 35 lbs/sq. in. pressure drop.

ciated wash water which would have to be included to be physically accurate was omitted because on a water-free basis superficial velocity can be used as a measure of oil-handling capacity. The correlations presented on superficial velocity were obtained from the data obtained on pilot plant A.

The results of the first series of runs devoted to superficial velocity are shown in Figure 2. Hastings

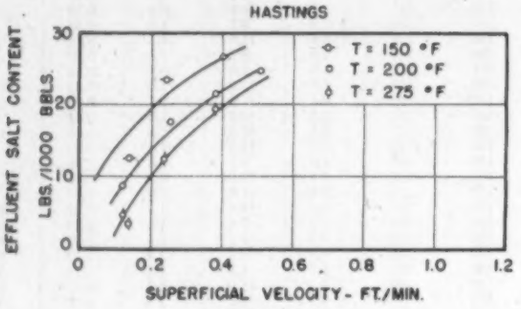


FIGURE 2

Effect of velocity and temperature at low water-to-oil ratio.

crude with an average initial salt content of 65.1 pounds per 1000 barrels was used and the water-to-oil ratio was arbitrarily fixed at 0.1/1. With the oil temperature in the contactor at 270° F. the effluent salt content increased from 4 pounds per 1000 barrels to 23 pounds per 1000 barrels as velocity was increased from 0.12 to 0.50 foot per minute. Similarly, at 150° F. the salt content was 10 pounds per 1000 barrels at 0.05 foot per minute but increased to 26.5 pounds per 1000 barrels at 0.4 foot per minute. The operating conditions during these runs were not the

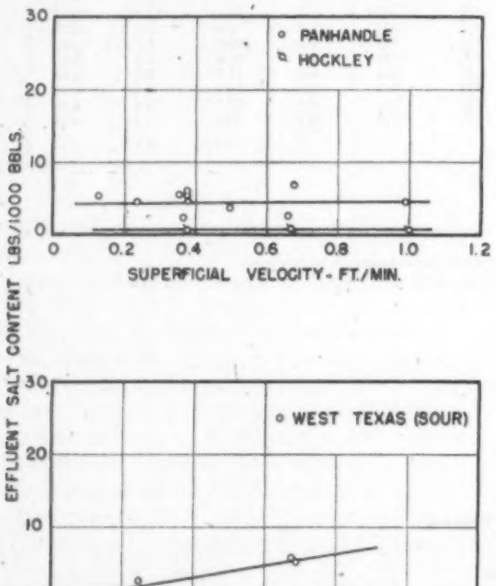


FIGURE 3

Effect of velocity at optimum water-to-oil ratio.

best as it will be shown later that an increase in water-to-oil ratio from 0.1/1 to 0.2/1 greatly facilitated the desalting of Hastings crude.

Other investigations of the effect of superficial velocity were carried out on Panhandle, Hockley, and West Texas (sour) crudes under more favorable conditions. The results are presented in Figure 5. In the case of Panhandle crude, two series of runs were made at water-to-oil ratios of 0.2/0 and 0.3/0 at a temperature of 230° F. The initial salt content was 50 pounds per 1000 barrels over the range of 0.1 to 1.0 foot per minute superficial velocity. Variation in water-to-oil ratio in the range of 0.2/1.0 to 0.3/1.0 seemed to have no significant effect on the salt content of the desalted oil.

The Hockley (also from West Texas and sour) crude which had a salt content of 272 pounds per 1000 barrels was processed at 275° F. at a water-to-oil ratio of 0.2/1.0. This crude was particularly easy to desalt. The salt content of the desalted oil was only 1 pound per 1000 barrels over the range of 0.38 to 1.0 foot per minute superficial velocity.

West Texas (sour) crude which was supplied by Magnolia Petroleum Company was also processed at

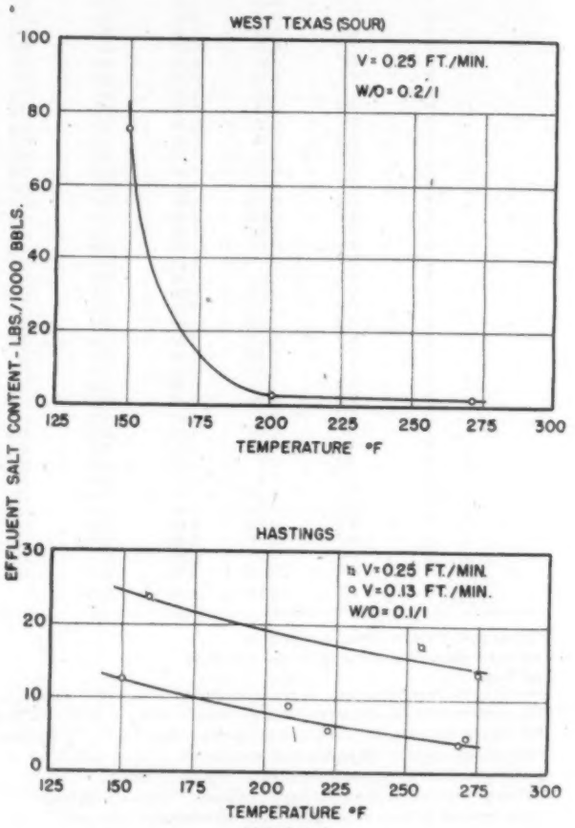


FIGURE 4

Relation of temperature to desalting.

275° F. and a water-to-oil ratio of 0.2/1.0. The initial salt content ranged from about 22 pounds to 45 pounds per 1000 barrels. The salt content of the desalted oil increased linearly from 1 pound per 1000 barrels at 0.13 foot per minute to about 6 pounds per 1000 barrels at 0.69 foot per minute superficial velocity.

It is evident, therefore, that the effect of superficial velocity is dependent to some extent on the type crude oil but perhaps to a greater extent on the water-to-oil ratio and temperature, particularly below the respective values of 0.1/1.0 and 200° F.

Temperature

The effect of temperature was investigated on pilot plant A. The significance of temperature on the desalting of Hastings and West Texas (sour) crudes is brought out graphically in Figure 4. The effluent

salt content of Hastings crude at 0.13 and 0.25 foot per minute decreased gradually as the operating temperature was raised from 150° F. to 275° F. At 0.13 foot per minute over this temperature range the decrease was from 12.8 to 4.0 pounds per 1000 barrels and at 0.25 foot per minute from 25 to 14 pounds per 1000 barrels.

The effect of temperature was much more pronounced with West Texas sour crude at 0.25 foot per minute and 0.2/1 water-to-oil ratio. In the temperature range of 200° F. to 275° F. good desalting was obtained since the effluent oil contained a maximum of 2 pounds of salt per 1000 barrels. As the temperature dropped below 200° F., however, desalting became poor and the effluent salt content reached 74.5 pounds per 1000 barrels at 150° F. This is higher than the initial salt content of the oil because at the lower temperature the Fiberglas beds were not capable of breaking the emulsions, nor was settling effective. Some of the wash water was carried out in the effluent oil.

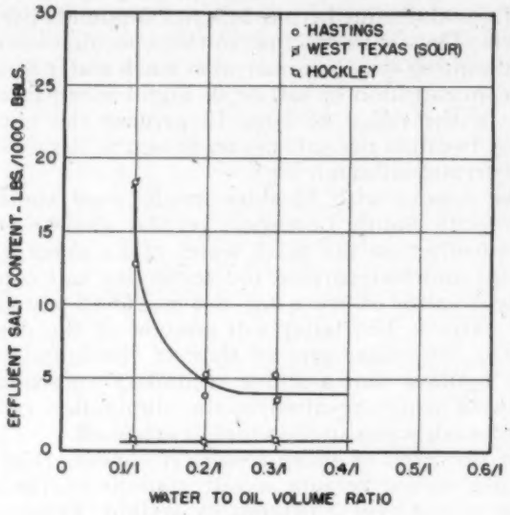


FIGURE 5
Effect of water-to-oil ratio.

It appears, then, that best desalting with most crudes requires that the operating temperature be above 250° F.

Water-to-Oil Ratio

Results from Pilot Plant A

The volumetric ratio of water to oil is one of the most important variables. Based on a large number of microscopic examinations, it is believed that salt in crude oil is almost always present as fairly concentrated salt water which is emulsified in the oil. Consequently the salt content can be reduced by intimate washing of the oil with water which has a low concentration of salt provided effective separation of wash water is obtained. Such a reduction is realized merely by dilution of the original brine that was emulsified in the oil.

It is evident that the amount of brine in even a relatively high salt content crude is very small. For example, a crude oil which contains 200 pounds of salt per 1000 barrels would correspond to 577 pounds of brine of 35 percent (weight) salt (chlorides expressed as NaCl). Thus the volume of brine would be about 0.17 percent of the oil. Furthermore, only about 700 gallons of fresh water would be required per 1000 barrels of crude oil to dilute the brine in the crude to less than 3 percent by weight of salt. Thus the amount of fresh water required for dilution is approximately 1 percent by volume of crude oil per 100 pounds of salt in the oil. This is predicated upon the assumption that complete contact between the brine and the fresh water is attained, which is entirely feasible.

In order to attain thorough contact between the brine in the crude oil and the wash water, it is necessary in most cases to use a relatively large amount of wash water. As the ratio of wash water to oil increases complete contact is approached. This can be accomplished in most cases with the theoretical minimum amount of fresh water by recycling the wash water. Heat economy also makes this desirable.

Figure 5 presents the results of variation in wash-water-to-oil volumetric ratio for three different crude oils. In the case of Hastings and West Texas (sour) crudes, it is noted that the effect of water to oil ratio is sharp in the range of 0 to 0.2/1.0. The effect of water-to-oil ratio on Hockley crude, however, was not great although it is probable that below a water-to-oil ratio of 0.1/1.0 a similar effect would be found.

The results on Hastings crude oil were obtained at 275° F. and 0.25 foot per minute superficial velocity whereas the results on West Texas (sour) crude were obtained at 260° F. and 0.67 foot per minute velocity. Even so it appears that the effect of water-to-oil ratio for these crudes can be correlated with a single curve.

On the basis of the results it appears that there is little to be gained by using a water-to-oil ratio in excess of 0.2/1.0.

Results from Pilot Plant B

Although the primary purpose of the investigation on pilot plant B was to study the life of Fiberglas packing, several data were obtained on the effect of water-to-oil ratio. In Run No. 4 (Table 2) a water-to-oil ratio of 0.25/1.0 at a superficial velocity of 0.5 foot per minute was maintained until March 20 when it was reduced to 0.125/1.0 merely by doubling the crude rate. This involved a change in two variables simultaneously but even so it is noted that there was little effect on the salt content of the desalted oil. Thus it appears from these data that a ratio of 0.125/1.0 is as high as necessary.

After a few experiments on recycling of water from the settler, the effect of wash-water-to-oil ratio was explored further. On April 2 and 3, it was reduced to 0.061/1.0 and it is observed that the salt content of the desalted oil increased to 98.0 and 69.0 pounds per 1000 barrels respectively. Then the ratio was increased to 0.125/1.0 on April 4 but the salt content of the desalted oil remained high. The water-to-oil ratio was therefore increased to 0.2/1.0 on April 5 to wash out the Fiberglas beds. The salt content of the desalted oil then dropped to a normal value.

After a few more experiments on recycling of wash water, the water-to-oil ratio was dropped from 0.125/1.0 on April 12 to 0.08/1.0 on April 13 and 14. Again the salt content of the desalted oil increased to excessively high values. Following this the water-to-oil ratio was returned to 0.125/1.0 and the salt content of the desalted oil dropped sharply to a normal value where it remained until the run was terminated voluntarily.

In all the results from pilot plant B the BS and W contents were substantially higher than obtained in the investigation on pilot plant A. Some of the same

crude oil has been processed on pilot plant A and no BS and W could be detected in the desalted oil after proper settling. This difference is still unexplained.

Salt Content of Wash Water

Results from Pilot Plant A

The amount of fresh water required is a function of the salt content of the crude oil and the salt content of the water rejected to the sewer. Hence, for a given salt content of the crude, the required amount of fresh water depends on the salt content maintained in the wash water when wash water is made up by recycling. It was desirable, therefore, to establish the effect of salt concentration of the wash water on salt content of desalted oil. Figure 6 presents the results which were obtained on two of the crude oils. In both cases the salt concentration of the wash (recycle) water was varied at constant values of temperature (275° F.), superficial velocity (0.25 foot per minute) and water-to-oil volumetric ratio (0.2/1.0). It will be noted that with South Louisiana crude, the salt content of the desalted oil increased with salt concentration of the wash water over the entire range investigated. As the salt concentration of the wash water was increased from 0.8 percent by weight to 3 percent by weight, the salt content of the desalted oil increased from 0.8 to 5 pounds per 1000 barrels. On the other hand it was found with West Texas (sour) crude oil that as the salt concentration of the wash water was increased from 0.5 to 22.5 percent by weight, the salt content of the desalted oil increased at first and then decreased. In the range of 0.5 to 3 percent by weight the salt content of the desalted oil increased from 4 pounds per 1000 barrels to 10 pounds per 1000 barrels. At 6.7 percent salt concentration of the wash water the salt content of the desalted oil was 57.2 pounds per 1000 barrels (noted in Figure 6 by an arrow). It appears therefore that the secondary emulsion which was created by passing the crude and wash water through the pump, was so stable that it was not resolved by the Fiberglas beds. As the salt concentration in the wash water was increased from 17 to 22.5 percent by weight the salt content of the desalted oil declined from 14.5 to 2.5 pounds per 1000 barrels. Thus it seems that in this specific case effective desalting was obtained with wash water of either low concentration of salt or of high concentration of salt. In the range of 5 to 17 percent the curve is dotted because the salt contents of the desalted oils were erratic although high.

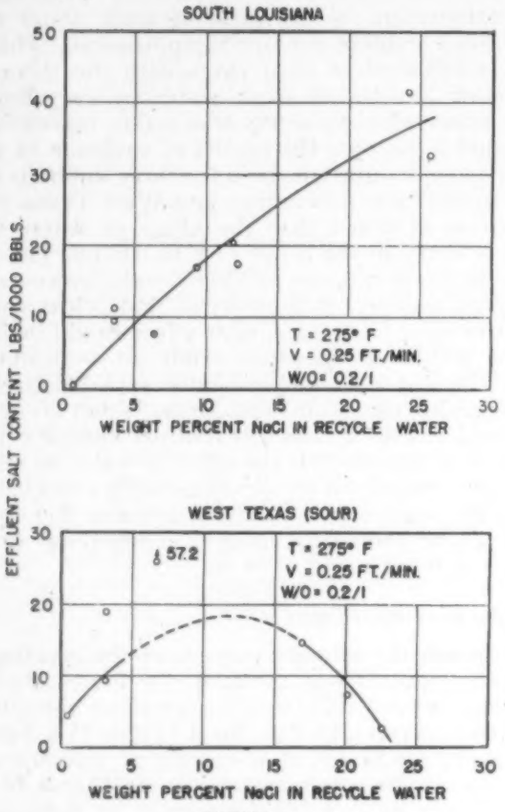


FIGURE 6
Variation of salt concentration in wash water.

The results with Hockley crude were similar to those with South Louisiana regular crude. At salt concentration in the wash water of 1.5 percent, 27.4 percent and 23.1 percent the respective salt contents of the desalted oil were 0.9, 44.2 and 584.2 pounds per 1000 barrels. The latter salt content of the desalted oil was somewhat greater than of the initial crude. This signifies that a stable secondary emulsion was produced which resulted in the elimination of some of the wash water in the effluent crude oil.

On the basis of these results it appears that good practice would require a salt content of the wash water of not over 3 percent by weight. Besides providing good desalting this has the added advantage of keeping salt deposition at a minimum in the event that poor operation permitted some water to be carried into the effluent.

Results from Pilot Plant B

During the period of March 27 to 29 recycling of wash water was carried out to determine the effect on desalting. From 10 a.m., March 27 to noon of March 28, the wash water was made up entirely of recycle water from the settler in order to build up the concentration of solids in the wash water as rapidly as possible. During this time both the salt content of BS and W of the desalted oil increased sharply.

Then from noon of March 28 to 3 p.m. of March 29 the wash water was made up of 50 percent recycle water and 50 percent fresh water. Both the salt content and BS and W of the desalted oil continued to rise. The salt content and BS and W finally reached values of 141 pounds per 1000 barrels and 7.0 percent respectively when recycling was terminated.

Again on April 10 and 11 recycling was investigated. The wash-water-to-oil ratio was maintained at 0.192/1.0 which consisted of 20 percent recycle water and 80 percent fresh water. It had been found previously that with this amount of fresh water good desalting was obtained but with the additional recycle water the salt content of the desalted crude increased to a value of 68 pounds per 1000 barrels on April 11. Then recycling of water was stopped but the amount of fresh water was held at the same rate. The salt content of the desalted oil again dropped to a normal value.

It appears from these data that recycling of wash water cannot be done with this crude without a detrimental effect. It was found, however, in later runs on pilot plant A on the same crude oil that very effective desalting could be obtained when recycling wash water. In this experimental work, the recycle wash water was maintained at 2 percent solids con-

centration but the initial wash water was made up to this concentration by dissolving NaCl in tap water. Thereafter fresh water was admitted to maintain the 2 percent concentration. Thus recycling is in need of further investigation.

Fiberglas Bed Thickness

Results from Pilot Plant A

Provision was made in the design of the contactors for obtaining samples from between the beds in order to determine the effect of bed depth. In run No. 15

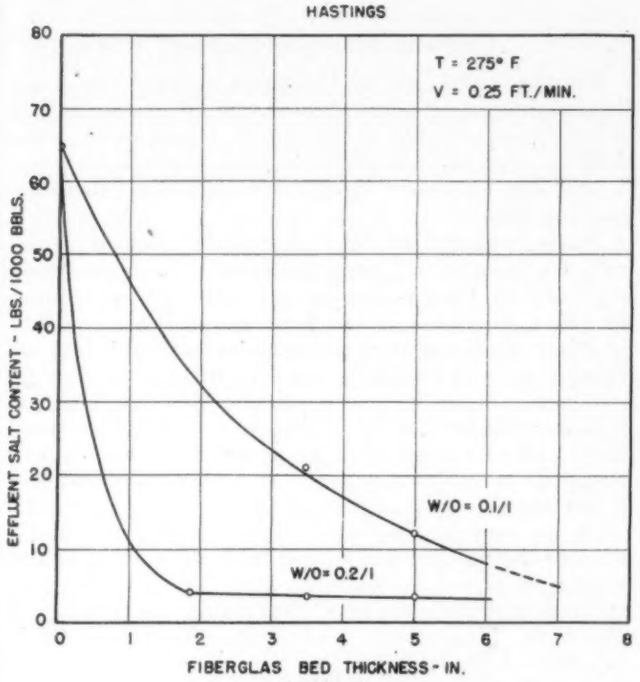


FIGURE 7
Variation of desalting with bed depth.

on Hastings crude oil (275° F., 0.25 foot per minute and 0.1/1.0 water-to-oil ratio) the salt content was reduced from 65.1 to 30.1 pounds per 1000 barrels in the first 1⅞ inches in depth. In the next 1⅝ inches the salt content declined to 21.2 pounds per 1000 barrels and in the final 1½ inches the salt content dropped to 12.8 pounds per 1000 barrels. These results are presented in Figure 7 along with results from run No. 16 which were obtained at a water-to-oil ratio of 0.2/1.0 but at the same temperature and superficial velocity. At the higher water-to-oil ratio the salt content of the desalted oil was reduced from 65.1 to 4.2 pounds per 1000 barrels in the first 1⅞ inches of bed depth and was not affected appreciably upon passing through the second and third beds. The same general effect was noted on Panhandle crude. A depth of 3 to 4 inches of Fiberglas packing seems to be all that is effective at a water-to-oil ratio of 0.2/1.0.

Results from Pilot Plant B

Run 4 was carried out with 5 individually supported beds each of 2 inches depth based on a bed density of 13 pounds per cubic foot. Run 5 was conducted with only 3 individually supported beds each of 1 inch depth when referred to a density of 13 pounds per cubic foot.

Although only limited conclusions can be drawn by comparing the results from the two runs, it appears that essentially as good desalting was obtained in Run 5 as in Run 4.

Fiberglas Bed Density

Results from Pilot Plant A

Essentially all of the experimental work was done with a Fiberglas bed density of 13 pounds per cubic foot because this gave consistently good results and could be easily obtained in commercial installations. It was desirable, however, to establish the effect of bed density in some detail. To facilitate the adjustment of bed density the support plates were removed from the 4-inch-diameter contactor and only one bed 7 inches deep was used in all runs.

Figure 8 is a correlation of the data on the effect of bed density with South Louisiana crude oil. As the density was increased from 9 to 15 pounds per cubic foot the salt content of the effluent oil decreased from 18.4 pounds per 1000 barrels (run No. 77) to 3.2 pounds per 1000 barrels (run No. 83). Densities above 15 pounds per cubic foot are undesirable because of the high pressure required to obtain them. It is probable also that such a high pressure tends to disintegrate the fibers upon compression.

The data on bed density were obtained at constant bed depth (7 inches) but the effect of density at constant amount of glass fiber surface is perhaps of equal importance. An indication of this can be obtained by a comparison of Figure 7 with Figure 8. Because of meager data, however, such a comparison is not entirely sound. Hence on the basis of data reported at this time, it is not certain but that essentially the same effect would be obtained within the range of densities investigated if the weight of glass fibers or surface area of the fibers in the bed were maintained constant.

In this investigation the Fiberglas beds were compressed to the desired density when installed. Based on the results from pilot plant B, this does not appear

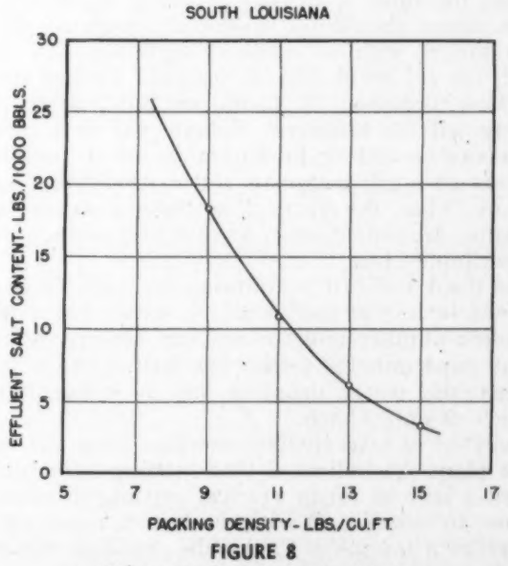


FIGURE 8
Effect of bed density on desalting.

necessary because the pressure drop through the beds seems to provide the desired density. Also the surface forces the water within the beds are no doubt of great importance. Thus the density which exists seems to be a direct function of the pressure gradient

through the bed. Hence, the effect as shown in Figure 7 is merely that of bed depth.

Results from Pilot Plant B

In Run No. 4 the contactor contained 5 individually supported beds each of 2 inches depth pre-compressed to 13 pounds per cubic foot density. In Run No. 5 the contactor contained only 3 individually supported beds each of 2 inches depth pre-compressed to 6.5 pounds per cubic foot density. Actually this density is little more than the density of the fibers as shipped from the factory.

When the contactor was opened after Run No. 5 was terminated, it was found that the beds had compressed to a depth of about 1 inch. This it appears from these data that pre-compression is unnecessary since the pressure drop through the beds caused by the flow of oil and water is sufficient to provide the desired density of the beds.

Settling Time

Unless proper settling is provided the desalted oil will carry over droplets of the wash water which are not present as an emulsion. This will result in high values of BS and W. Although proper settling is not a problem in the actual demulsification, it is nevertheless an important feature of the process because it can seriously limit the capacity of a desalting plant. In view of this a few pertinent data were obtained to permit the design of settlers for the process. Results were obtained by taking samples of oil from various intermediate points within the settler on all the crude oils investigated with exception of Hastings.

On the basis of the results obtained on pilot plant A and the theory of free settling, it is concluded that there are five conditions which should be met in order to insure the desired settling. First, temperature should be maintained as high as is feasible—preferably at the same value as the contactor. As temperature increases, the viscosity of the oil decreases as does the ratio of density of oil to water. Second, the pressure should be sufficiently high so that no vaporization with attendant agitation will occur. Third, the settler should be designed so that streamline flow prevails. If turbulent flow takes place, settling will be hindered. Fourth, the flow through the settler should be horizontal so as to permit the droplets of wash water to settle unaffected by the oil flow. Five, the vertical settling distance before the water droplets contact a collecting surface should be maintained low.

The third and fifth conditions perhaps can best be obtained by use of baffles which reduce the effective Reynolds number and the vertical settling distance. In the experimental settler the baffles were spaced so that the water droplets had to settle a mean distance of only 1 inch.

Analyses of intermediate samples from the settler (pilot plant A) indicated that settling velocities exceeded 1 inch of mean vertical settling distance per minute. In run No. 33 with the baffles removed from the settler a sample of Panhandle crude oil was taken 7 inches from the inlet of the settler. This corresponds to 4.6 minutes residence time with the water level at ⅓ the diameter of the vessel. The sample contained no free water and 5.3 pounds of salt per 1000 barrels which is identical with the salt content of the settler effluent after 17 minutes residence time. Another sample which was taken in run No. 34 3 inches from the inlet point (1.9 minutes residence time) contained no free water and 5.1 pounds of salt per 1000 barrels. The effluent oil contained 4.7 pounds per 1000 barrels which for all practical purposes may be regarded the same as the intermediate sample. Samples taken during subsequent runs showed the same relationship. More settling time was required with West Texas (sour) crude oil than in the case of the other crudes, however, and baffles were required in the settler to obtain desired results. Probably in this case a higher temperature than used in the experimental work would be beneficial both to demulsification and settling.

Life of Fiberglas Packing

Results on the life of Fiberglas packing could not be determined on pilot plant A owing to the lack of a continuous supply of crude oil. Consequently life studies were made entirely on pilot plant B. Run No. 4 provides the most conclusive data on Fiberglas-packing life.

During the first 28 days of Run No. 4, a superficial velocity of 0.5 foot per minute with a water-to-oil ratio of 0.25/1.0 was maintained with the exception of March 4 to 6 inclusive, when the velocity was 0.75 foot per minute with a water-to-oil ratio of 0.167/1.0. During the next 29 days the velocity was held at 1.0 foot per minute. However, during this latter period considerable exploring of the effect of water-to-oil ratio and recycling of wash water was done which resulted in poor desalting at times. Nevertheless when the water-to-oil ratio was fixed at 0.125/1.0 with no recycling of wash water during the last 3 days of the run, good desalting was obtained. The run was terminated voluntarily after 57 days of continuous operation without exhausting the efficacy of the beds. How much longer the life would be is problematical. However, at the end of the run the pressure drop through the contactor was only 3 pounds per square inch. This would indicate that a substantially longer life could be expected.

When the contactor was opened at the end of the run, it was found that the top bed had a hole of about 1.5 inches in diameter which extended to the supporting screen. The second bed from the top had about 40 percent open area. The Fiberglas packing had been pushed to one side. The third bed from the top had two holes each of about 0.5 inches in diameter at the sides of the bed. The fourth bed was in good condition with no holes or channels. The bottom bed had channels about 0.25 inches wide around the outside of the bed. Thus it appears on the basis of these observations that one bed was giving about 95 percent salt removal.

At the conclusion of Run No. 5 the contactor was opened and it was found that the top bed had a hole of about 0.5 inches in diameter which extended to the supporting screen. The second and third beds, however, were in good condition. Each had compressed to about 1 inch in depth as mentioned previously. It appears that the top bed may receive the most severe treatment and its life is, therefore, relatively short.

It is believed that pressure drop is the cause of the loss of life of the packing. If a pressure drop of not over 5 pounds per square inch is permitted across any bed, its life would be expected to be almost indefinite. It seems that as pressure drop increases, the beds compress so that silt is filtered out, which

results in rapid increase in pressure drop and exhaustion of bed life.

Type Mixing

In the investigation of pilot plant B two types of mixing were tried for contacting the wash water and oil. The ideal type of mixing is that in which intimate contact between oil and wash water is obtained without the formation of any secondary emulsion.

During the first 12 days of Run No. 4 the wash water was admitted to the discharge of the crude oil pump and mixing was obtained by expanding the oil and water through a globe valve with a 35-psi pressure drop. Then the point of admitting wash water was changed to the suction of the pump. Mixing of the oil and wash water was attained by the gears of the pump. Hence, the globe valve was not used.

Based on these data for the first few days preceeding and following the change in method of mixing, it appears that better results were obtained when using the gear-type pump for mixing.

In Run No. 5, the two methods of mixing were again studied. The pump was used for the first six days. Then the globe valve was used for four days and finally the pump was used for the last two days of the run. It is quite apparent from the salt contents and BS and W of the desalted oil that substantially better results were obtained by use of the gear-type pump. Also, it is felt that the globe valve produces somewhat more secondary emulsion which is stable and causes excessive pressure drop.

Commercial Application

Although the process using Fiberglas packing for desalting of crude oil is very attractive from the standpoint of commercial application, there is still some development to be done before the best designs can be made. This is in progress at present.

The work reported at this time was done with both wash water and crude oil passing through the Fiberglas beds. It is entirely possible that better results could be obtained if a pre-settler were located just prior to the contactor to remove a portion of the free water. This would reduce the true linear velocity through the contactor so that a low pressure drop would be incurred. Investigation of this is now in progress as an extension of this work.

Design of Commercial Units

There remains additional development work but the results thus far provide a basis for design of units which appear to be competitive with any desalting process now available. A preliminary economic study was made for a 10,000-barrel-per-day desalting unit. This is estimated to require an investment cost based on API-ASME code of $3.70 per barrel of daily capacity. The cost of operation based on amortizing the investment over a 5-year period was estimated to be as follows:

BED LIFE DAYS	Dollars per Barrel	
	Excluding Amortization	Including Amortization
60	0.001917	0.003857
90	0.001428	0.003368
120	0.001183	0.003123
180	0.000940	0.002880

The economic study was based on desalting a 28° API crude oil of 100 pounds per 1000 barrels salt content at 275° F., 1.0 foot per minute superficial velocity, 5 individually supported beds of Fiberglas basic fibers, averaging 0.00028 inch in diameter, each bed of 2 inches depth, 6.5 pounds per cubic foot density, 0.2/1.0 water-to-oil volumetric ratio, 2.5 percent by weight of salt in the wash water and an average pressure drop across the beds of 30 pounds per square inch. The settler design was based on 10 minutes residence time with 6-inch spacing between baffles. It was assumed that power costs $0.01/KWH, heat is worth $0.30 per million Btu and labor costs $1.25 per man hour. The cost of the basic glass fibers as tentatively established by the manufacturer is $2.00 per pound.

Conclusions

Effective desalting of crude petroleum to less than 5 pounds of salt per 1000 barrels can be obtained by using beds of Fiberglas, basic fibers averaging 0.00028 inch diameter. It appears that the cost of the process is attractive for commercial application.

Effective desalting was obtained at a superficial velocity in the range of 0.25 to 1.5 feet per minute through the contactor based only on oil flow rate. The proper superficial velocity is dependent upon the type crude oil being processed. Temperature should normally be in the range of 250° F. to 350° F. and the water-to-oil ratio generally should be in the range of 0.1/1.0 to 0.2/1.0. Salt content of the wash water should not exceed 3.0 percent by weight. The total depth of Fiberglas beds required is ordinarily 6 to 10 inches at a density of 6.5 pounds per cubic foot. The beds should be installed so that no bed is of greater depth than 2 inches and each bed should be individually supported. Pre-compression of the beds is not necessary.

Settling after the contactor should be carried out in a horizontal settler with as high a temperature as possible. It should be designed for streamline flow and minimum vertical settling distance. Residence time should be established on the basis of a minimum of one minute per inch of mean vertical settling distance.

The life of Fiberglas packing is probably well in excess of 60 days—perhaps as long as 180 days. The principle cause of disintegration of the glass-fiber beds is excessive pressure drop. The pressure drop through a single bed should never be allowed to exceed 40 pounds per square inch. A desirable pressure gradient is 5 pounds per bed.

The most effective type mixer for contacting wash water and oil is a gear type mixer such as a gear pump.

ACKNOWLEDGEMENT

The author wishes to express his appreciation to Standard Oil Company (Indiana) for its courtesy in permitting the publication of data obtained on the pilot plant at Whiting, Indiana. Also thanks are due to the American Institute of Chemical Engineers for permission to reproduce portions of the paper by T. A. Burtis and C. G. Kirkbride, Trans. A. I. Ch. E. 42, June 25, 1946.

REFERENCES

[1] Burtis, T. A. and Kirkbride, C. G., Trans. A. I. Ch. E. 42, June 25, 1946.

Pressure Distillate Tower in Independent Refining Company's Refinery at Arp, in East Texas.

Efficient Operation Obtained In East Texas Refinery

L. S. DANIELS, Associate Editor

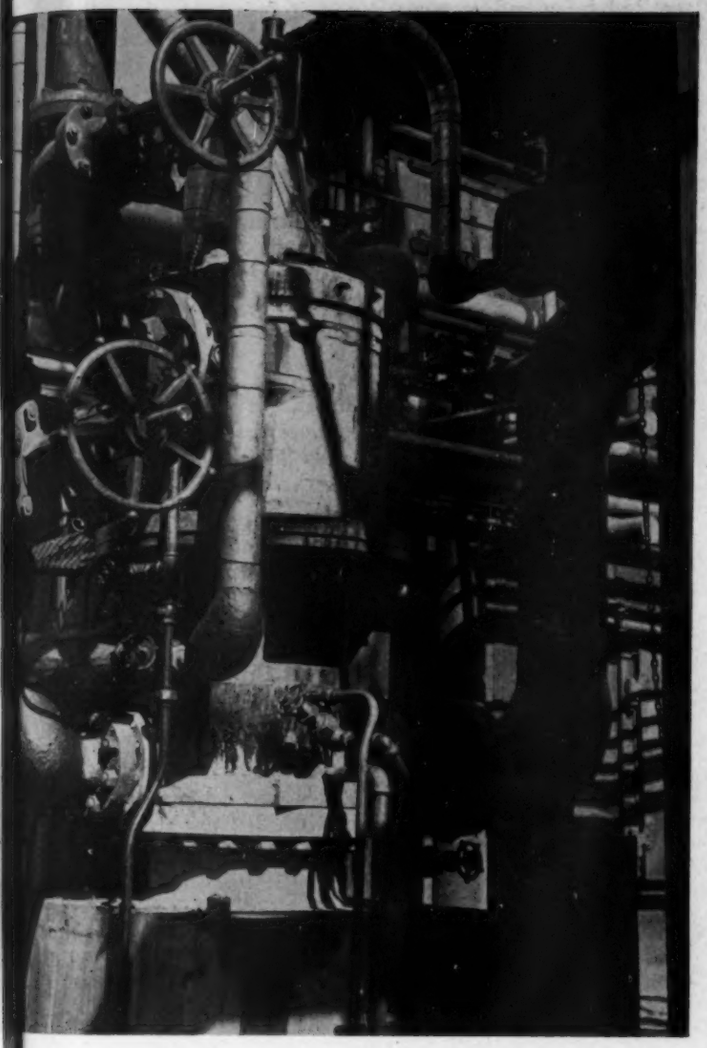
REPEATED alterations and improvements by Independent Refining Company, Arp, Texas, have resulted in a combination unit which permits efficient and economical processing of East Texas crude oil. The original plant, placed in operation in March, 1934, has been through extensive alteration programs in 1942, 1943, and 1945, with the result that the installation has been completely rebuilt.

Current yields of products based on fresh-crude liquid volume are: straight-run gasoline 24.3 percent, cracked gasoline 28.0 percent, polymer gasoline 1.0 percent, Stoddard solvent 5.72 percent, kerosine 7.73 percent, cracked gasoil 7.6 percent, and cracked fuel oil 22.8 percent. Approximately 50 percent of production is made into regular or housebrand gasoline having an octane of 75 plus, using 1.4 c. c. of lead, and about 50 percent manufactured into Ethyl gasoline, the Ethyl gasoline blend consisting of 40 percent cracked, 55 percent straight-run, and 5 percent polymer gasoline, using 2.7 c. c. of lead, and having an octane of 80 plus. Summer vapor pressure of housebrand gasoline is 8.5 RVP, and the Ethyl, 9.0 RVP. During the winter months approximately 10 percent of 18.0 RVP natural gasoline is used in each blend, and the vapor pressures are held at around 12.0 RVP.

Construction during the several modernization programs has been accomplished by the refinery staff: C. W. Curtis, refinery manager, C. Zimmerman, superintendent, A. P. Johnson, chief chemist, and O. C. Robertson, assistant superintendent.

Equipment

The present refinery consists of a combination crude-distillation, thermal-cracking, and gas-polymer-



Above is shown the hot-oil-charge pump for gasoil cracking coil.

At right is view of pumps and steam deaerator; the vertical shaft centrifugal in center of this group is the crude-oil charge pump.

ization unit, together with attendant steam-generating and water-cooling facilities, gasoline-blending equipment, crude and products storage tankage, product loading racks, laboratory, and administration building.

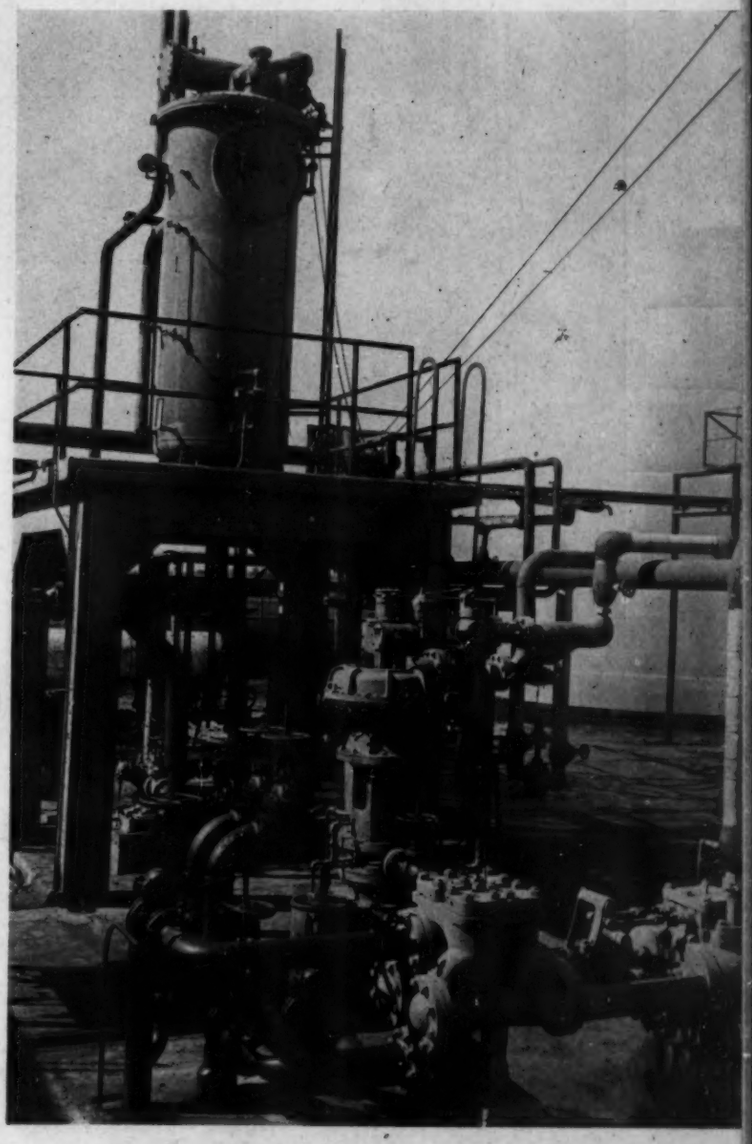
The combination unit, as shown on the flow diagram, Figure 1, has a charge rate of 4000 barrels per stream day of 36-38° API crude oil obtained from the East Texas field. Salt content of the crude charge has been reasonably low and no special provisions for crude desalting have been necessary. Crude is charged to the unit by means of a vertical-shaft turbine-driven centrifugal pump under rate-of-flow control, passes through heat exchangers on the hot straight-run gasoil and cracked-residuum product streams, being preheated therein to approximately 480° F., flows through the heating coil of the crude furnace which it leaves at 680° F., and into the straight-run flash tower. The straight-run flash tower operates at 38 psig, distillate vapors flow overhead to the crude tower, and topped crude bottoms, some 2000 barrels per stream day, are charged to reduced-crude cracking.

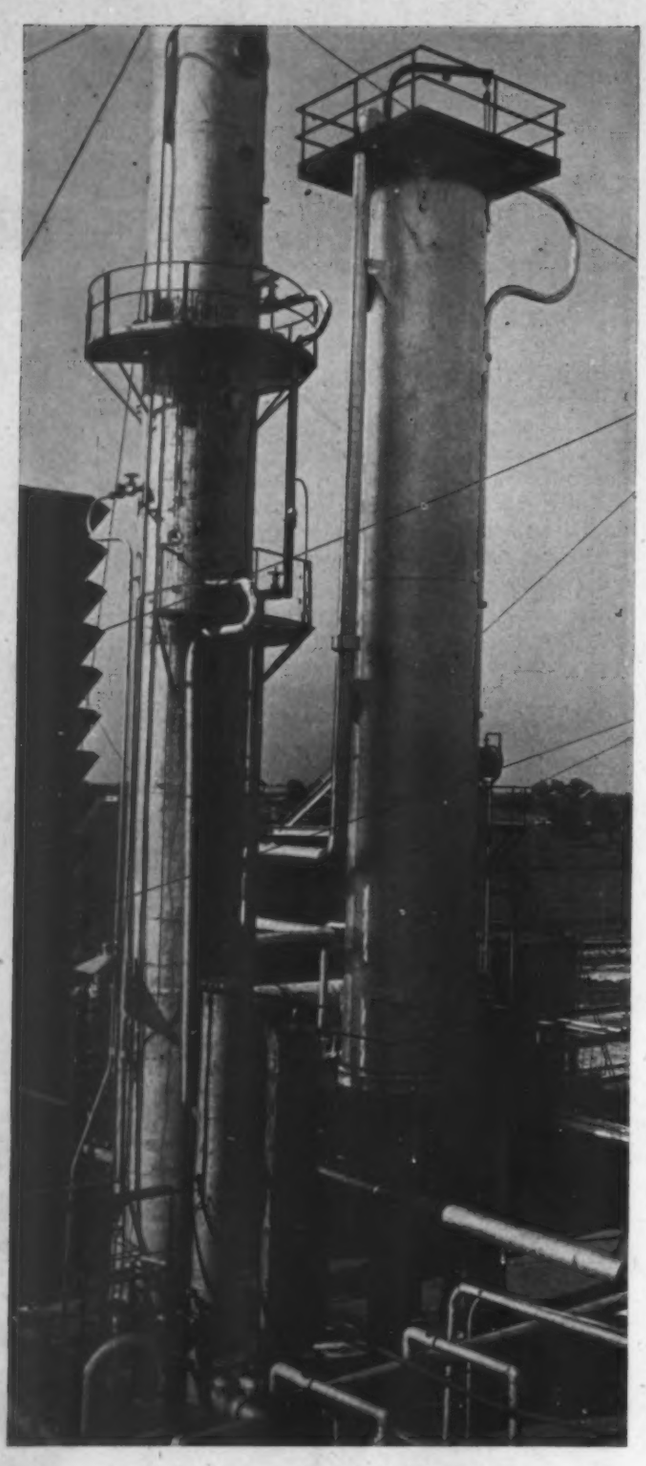
The crude tower produces straight-run gasoline overhead, naphtha and kerosine side streams, and straight-run gasoil bottoms. The naphtha side stream is led under flow control to a special tower equipped with reboiler and reflux condenser, which provide the sharp fractionation necessary for the production of Stoddard solvent and other specialty naphthas.

A gasoil stream is withdrawn from the base of the crude tower to furnish reboiler heat for the naphtha tower, the cooled gasoil flowing to the crude tower where it enters over baffles in the base and serves as intermediate reflux.

The kerosine side stream is led under flow-control to a steam stripper. Overhead vapors from this kerosine stripper are condensed and sent to storage, eventually being used as cracking-section feed stock. Side stream products flow to storage under liquid-level control, passing through suitable coolers. Straight-run gasoline plus top tower reflux is condensed overhead. The raw gasoline is charged to a stabilizer where a stabilized gasoline product is produced and flows to storage through a stabilizer-feed preheat exchanger and a product cooler.

Reduced crude bottoms from the straight-run flash tower are charged by a hot-oil pump to a single-pass cracking coil in the crude furnace. Effluent from this coil, at 840° F., and 350 psig, combines with effluent from the gasoil-cracking furnace. The resulting mixture, at a temperature of 905° F., enters the reaction





Crude-oil flash tower and crude-oil fractionator.

chamber where it is held until the cracking reactions are completed. This vessel operates at 250 psig, and cracked products plus recycle gasoil flow from the bottom through a slide valve which holds back pressure on the reactor and cracking coils and into the P.D. flash tower.

In the P.D. flash tower which operates at some 60 psig, cracked residuum is produced as a bottoms product, flowing to storage under level control and passing through a residuum-to-crude preheat exchanger. Cracked-distillate vapors plus recycle-gasoil vapors are produced overhead. Endpoint of overhead gasoil and properties of cracked residuum are controlled by a reflux stream which is admitted to the top of this vessel through a weighted spray nozzle.

Vapors from the P.D. flash tower, at about 780° F. enter the P.D. tower. In this tower cracked gasoline is produced overhead, a cracked gasoil sidestream is withdrawn, steam stripped, cooled and sent to storage, and gasoil-cracking-furnace charge, consisting of straight-run gasoil, gasoil from reduced-crude cracking, and recycle gasoil, is accumulated in the tower base. Liquid level in this base is maintained by controlling flow to the tower, from storage, of straight-run gas oil, kerosine strippings, etc., which are fed in a combined stream by a reciprocating steam pump.

Gasoil at 665° F. is charged to the gasoil-cracking furnace by a vertical-shaft turbine-driven centrifugal hot-oil pump under rate-of-flow control, at about 4400 barrels per stream day, and is heated to cracking conditions, leaving the furnace at 930° F. and combining with the outlet stream from the crude furnace, as previously described. Cracked gasoline plus top tower reflux from the P.D. tower is condensed overhead and raw cracked gasoline is charged to the cracked-gasoline stabilizer, where it is fractionated to the desired vapor pressure and sent to storage through a stabilizer-feed-preheat exchanger and a product cooler.

Cracked gases from the P.D. tower reflux drum flow to the absorber where the heavier and more valuable components are absorbed by contacting the gas stream with cool lean oil. Lean oil is obtained from the gasoil sidestream drawoff at the P.D. tower, is cooled, and flows to the top absorber tray, all under P.D. tower pressure. Rich oil from the absorber base is pumped back to the P.D. tower where the absorbed gases are flashed off. Tail gas leaves the absorber under back-pressure control. This control sets the pressure of the entire section fractionation system, back to the reaction chamber slide valve.

Polymerization Unit

Gases eliminated overhead from the cracked-gasoline stabilizer constitute the charge for the catalytic polymerization unit. They are compressed from 175 psig stabilizer pressure to about 300 psig, cooled, and flow to the poly feed stripping tower. This stripping tower is operated as a partial depropanizer, and serves to eliminate a considerable volume of light gases including H_2S which is undesirable in the poly unit feed. Bottoms from this feed-stripping tower are contacted with caustic solution for further hydrogen sulfide removal, cooled, settled, and charged to the polymerization reactors, flowing through a reactor effluent-feed exchanger and a feed preheater.

Feed temperature to the reactors is 325° F., reactor pressure is 400 psig, and exit temperature is about 350° F. A recycle stream is used to control the concentration of olefins in the reactor feed. No means for cooling the reactors is provided and no liquid quench of the catalyst chambers is practiced.

Effluent from the poly reactors flows to the polymer-gasoline stabilizer where it is fractionated to the desired vapor pressure. Reflux is condensed overhead and a portion of this material is used as recycle to the poly feed.

Heat for the two stabilizer towers of the unit, and for the poly fractionators, is supplied by means of a gasoil stream from the base of the P.D. tower. This gasoil stream is also provided with a cooler, and is returned to the P.D. flash tower as top tower reflux

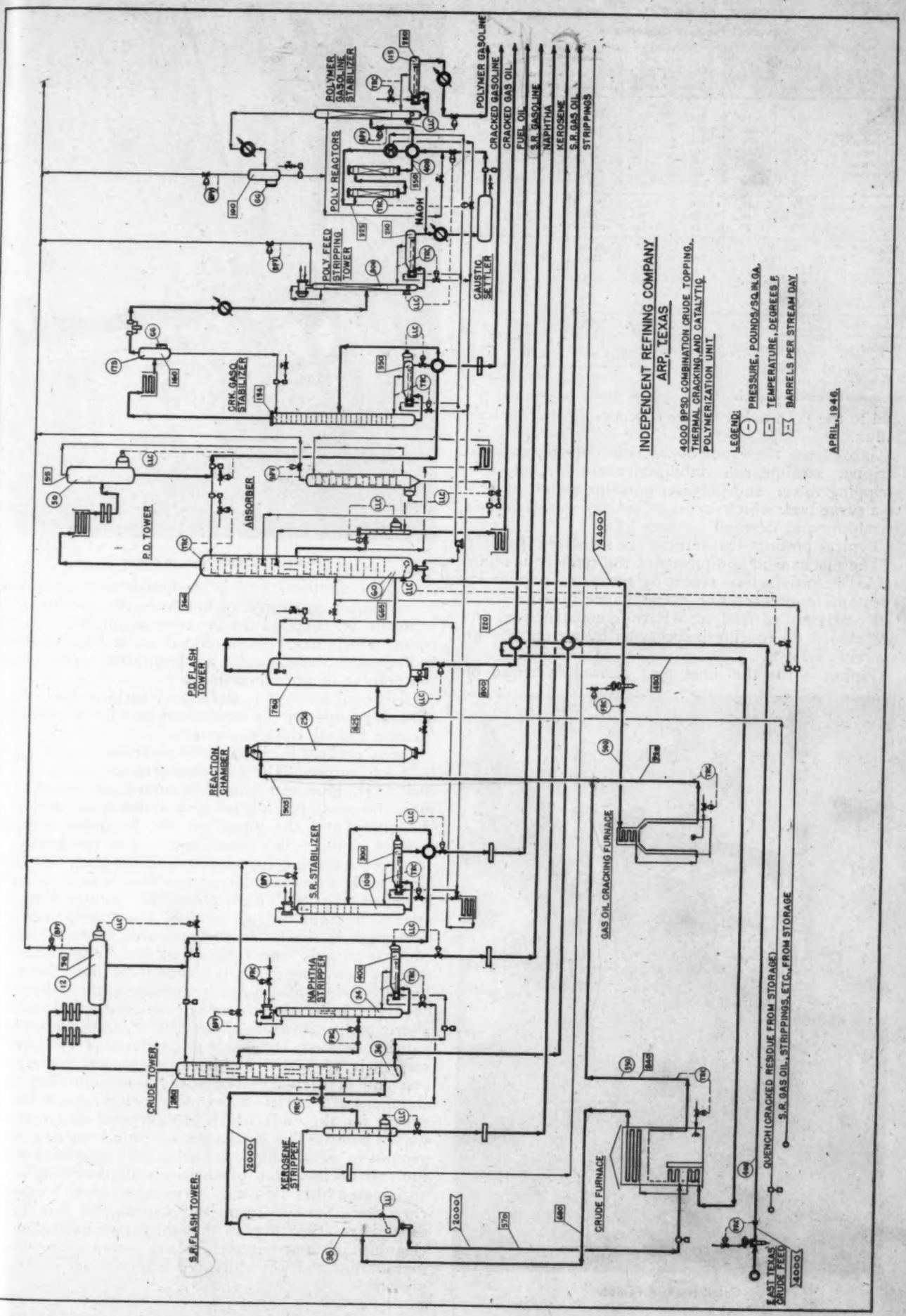

INDEPENDENT REFINING COMPANY
ARP, TEXAS
4000 BPSD COMBINATION CRUDE TOPPING, THERMAL CRACKING, AND CATALYTIC POLYMERIZATION UNIT
LEGEND:
PRESSURE, POUNDS/SQ.IN.GA.
TEMPERATURE, DEGREES F
BARRELS PER STREAM DAY
APRIL, 1946.
POLYMER GASOLINE
CRACKED GASOLINE
CRACKED GAS OIL
FUEL OIL
S.R. GASOLINE
NAPHTHA
KEROSENE
S.R. GAS OIL
STRIPPINGS
POLYMER GASOLINE STABILIZER
POLY REACTORS
POLY FEED STRIPPING TOWER
NaOH
CAUSTIC SETTLER
CRK. GASO. STABILIZER
ABSORBER
P.D. TOWER
P.D. FLASH TOWER
REACTION CHAMBER
S.R. STABILIZER
NAPHTHA STRIPPER
CRUDE TOWER
KEROSENE STRIPPER
S.R. FLASH TOWER
GAS OIL CRACKING FURNACE
CRUDE FURNACE
QUENCH (CRACKED RESIDUE FROM STORAGE)
S.R. GAS OIL, STRIPPINGS, ETC., FROM STORAGE
EAST TEXAS CRUDE FEED
4000
4400
2000
2000
570

TABLE 1
Typical Product Inspections

	Straight Run Gasoline	Stoddard Solvent	Kerosene	Cracked Gasoline	Cracked Gas-oil	Cracked Residuum	Polymer Gasoline
ASTM:							
I.B.P.	90	314	316	89	357	...	...
10 percent	137	328	394	141	433	...	...
30 percent	183	336	425	204	...	...	...
50 percent	218	344	439	261	475	...	...
70 percent	247	352	452	311	...	...	...
90 percent	294	367	480	368	535	...	...
F.B.P.	332	398	520	404	603	...	430
Percent Rec.	98	99	99	98	...	...	...
A.P.I.	66.0	46.8	41.4	58.7	34.0	12.0	...
Color	30	30	28	Yellow	—2	...	...
Sulphur	.019	...	...	0.065	0.188	...	...
Flash	...	113	127	...	150	290	...
R.V.P.	12.5	...	...	9.0	...	...	...
ASTM Clear Octane	67.0	...	...	64.3	...	...	83
Cetane No.	...	...	...	...	43	...	...
Viscosity	...	...	...	...	...	134 S.F. @ 122° F.	...
B. S. & W.	...	...	...	...	...	0.2	...

and to the P.D. tower where it serves as intermediate reflux.

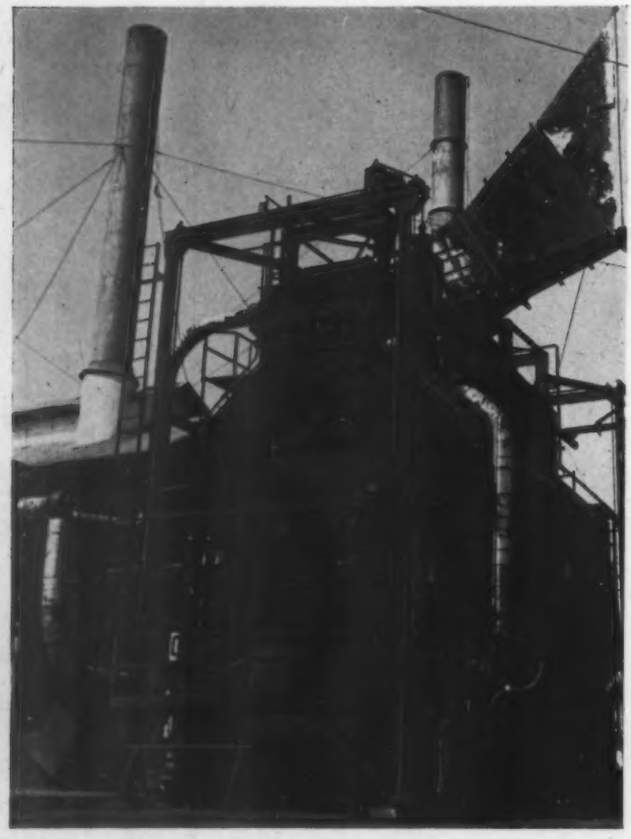
Gases from the crude-tower reflux drum, naphtha stripper, straight-run stabilizer, absorber, poly-feed stripping tower, and polymer-gasoline stabilizer flow to a surge tank which serves to balance out variations in supply and demand for fuel gas.

Typical product inspections are shown in Table 1.

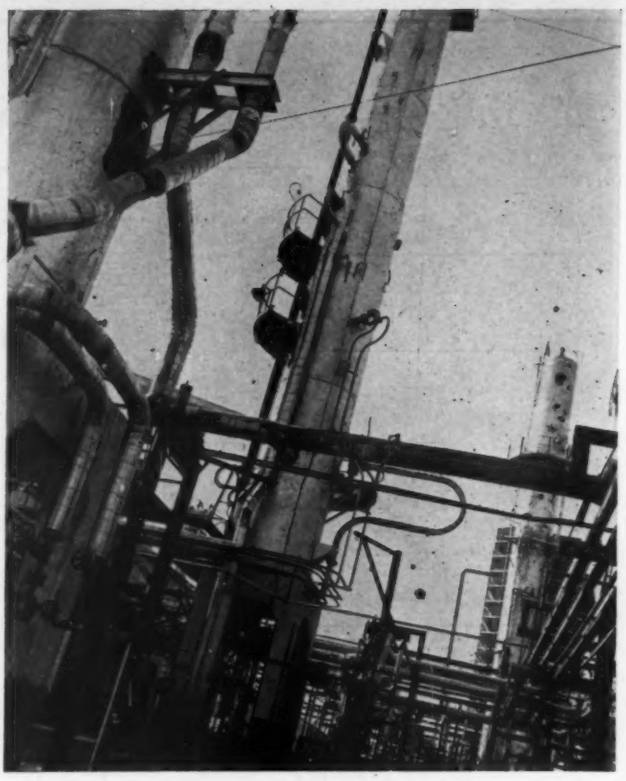
The mechanical equipment of the refinery is maintained in satisfactory repair by means of regular inspections and corrective maintenance measures.

Vessels are of API-ASME code construction, and are subject to routine inspections by an outside inspection service.

Piping is for the most part carried overhead on steel pipe supports and is designed with adequate provision for expansion of hot lines and vessels.



Gasoil-cracking Furnace



Pressure-distillate tower in center

Steam is supplied by a cross-drum water-tube boiler which has been mounted on a high firebox and operates satisfactorily at about 1200 horsepower, 200 percent of normal rating.

Of special interest is the use of turbine-drive centrifugal pumps for the crude feed, and for the gasoil-furnace hot-oil charge services.

Crude preheat is obtained by means of double pipe heat exchangers. These exchangers are made of 7-inch O.D. pipe and 4-inch Standard seamless steel pipe, the crude flowing in the annular space between the pipes, and the gasoil or the residuum stream flowing in the 4-inch center pipes. The residuum-to-crude exchanger consists of 3 sections each 350 feet long, with series countercurrent flow. The residuum is cooled from 800° F. to about 220° F. and flows to storage without further cooling. The gasoil-to-crude exchanger is similar to the residuum exchanger but consists of only one 350-foot section, with countercurrent flow. The gasoil is cooled from about 500° F. to 100° F. and also flows to storage without further cooling. The crude stream is preheated from atmospheric temperatures to about 480° F. Differential expansion between the inside and outside pipes of each section is permitted by means of packed glands at one end of each 350-foot straight section. The exchangers are buried a few feet below grade level, except for the ends which are exposed in concrete-walled sumps. The exchangers are not insulated; the ground in which they are buried was saturated with fuel oil at the time of their installation and it is anticipated that this will serve to prevent external corrosion. Service from the exchangers has been especially satisfactory in that they have not required cleaning in approximately three years since their installation and yet still give a high level of crude preheat.

Basic Petroleum Chemistry For Refinery Employes

J. J. STADTHERR, Resident Chemist
The Pure Oil Company, Heath Refinery, Newark, Ohio

Chapter V
CATALYTIC CRACKING PROCESSES

THE structure of petroleum molecules may be changed by methods other than thermal cracking. Not so many years ago the word "catalyst" was used only by a few advanced students of chemistry, and it was referred to only briefly in general chemistry textbooks. Today the word is used freely by people both in and outside the chemical profession, because catalysts are being used by thousands of industrial workers to aid in the production of synthetic rubber, high-octane gasoline, lubricating oil and many other chemical substances.

The word "catalyst" comes from two Greek words meaning dissolution, destruction, or decomposition. While the first uses of catalysts were for the decomposition of molecules, today catalysts also are used to build molecules to meet specific needs. Facilitated by the use of catalysts, molecules of styrene and butadiene combine faster and more completely to form molecules of synthetic rubber. Numerous other products such as toluene, isooctane, cumene, neohexane and ethyl-benzene are made more easily and in larger volumes with the aid of substances which act as catalysts.

Chemical texts define a catalyst as a substance which speeds up or retards a chemical reaction without itself undergoing a chemical change. Among the catalysts used in petroleum refining are included such materials as activated clay, aluminum hydrosilicates, fuller's earth, anhydrous aluminum chloride, sulfuric acid, phosphoric acid, hydrogen fluoride, chromium, molybdenum, nickel, vanadium and aluminum oxides, and many other substances.

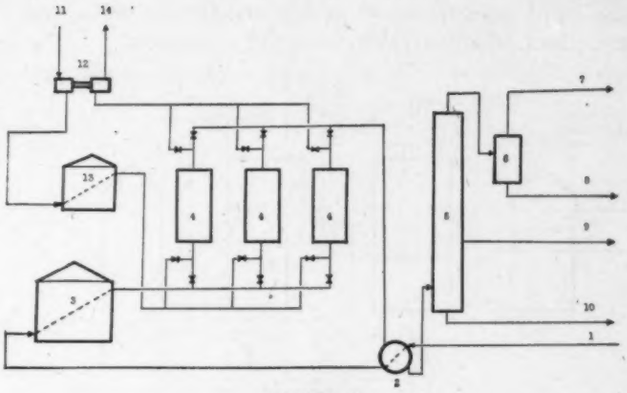
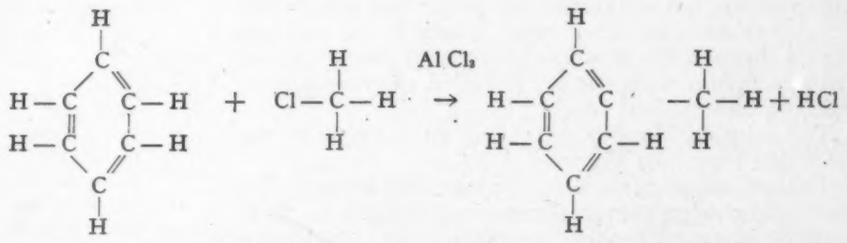


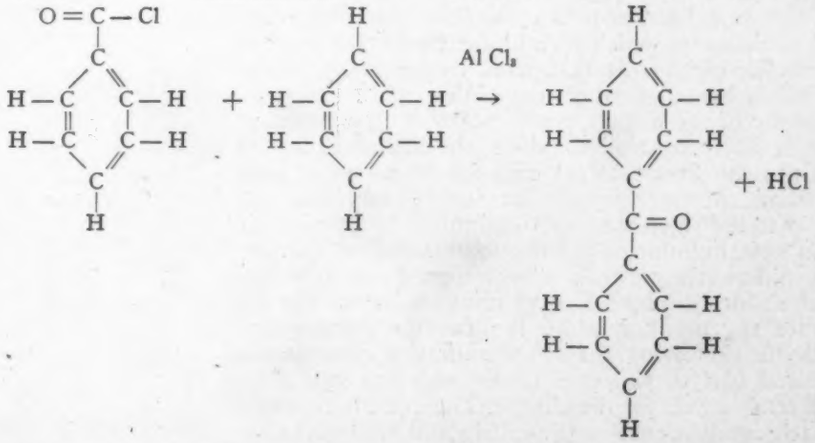
FIGURE 4
Houdry Catalytic-Cracking Process

1 Charge; 2 Heat Exchanger; 3 Charge Heater; 4 Catalyst Cases; 5 Fractionator; 6 Separator; 7 Wet Gas; 8 Gasoline; 9 Naphtha; 10 Catalytic Gasoil; 11 Fresh Air; 12 Turbo-Compressor; 13 Air Heater; 14 Flue Gas.

chemists who made use about 80 years ago of anhydrous aluminum chloride to cause such reactions as the following:



Benzene + Chloromethane → Toluene + Hydrochloric Acid



Benzoyl Chloride + Benzene → Benzophenone + Hydrochloric Acid

(Al Cl₃) Anhydrous aluminum chloride in each case is used as a catalyst.

Catalytic Cracking

It seems that the first use of a catalyst in hydrocarbon synthesis was made by Charles Friedel (French) and James Mason Crafts (American), The process of A. M. McAfee, U. S. Patent 1,127,465, and G. W. Gray, U. S. Patents 1,193,540 and 1,193,541, were applications of the Friedel-Crafts type

reaction to petroleum refining. These patents were issued in 1915 and 1916. McAfee's patent was assigned to Gulf Refining Company, and that company constructed a commercial unit at Port Arthur, Texas, in 1916. The high cost of anhydrous aluminum chloride and the difficulty of separating the catalyst from the tarry residue prevented wide use of the process.[1]

Although many refining processes, using some type of catalyst, had been patented, it was not until 1933 that a successful catalytic-cracking operation was shown to be commercially successful. This was the Houdry process, invented by Eugene Houdry and originally demonstrated at the Paulsboro, New Jersey, plant of Socony-Vacuum Oil Company.

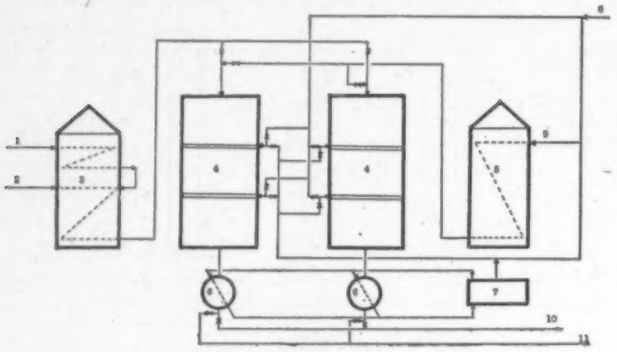


FIGURE 5
Cycloversion Catalytic Cracking Process

1 Steam; 2 Charge; Steam and Charge Heater; 4 Catalyst Cases; 1 Steam; 2 Charge; 3 Steam and Charge Heater; 4 Catalyst Cases; Compressed Air; 9 Steam and Air; 10 Gasoline to Fractionating Tower; 11 Flue Gas to Vent.

Catalytic-cracking processes in use today are of two types, typified by the manner in which the catalyst is applied to the operation. One type is referred to as the stationary, fixed- or static-bed type in which the catalysts remain stationary in the reaction chambers or cases. The other type, in which the catalyst moves through the reaction zone either concurrent or countercurrent with the oil, is called the continuous, fluid, or moving-bed type.

The original Houdry process is an example of the fixed-bed type. See Figure 4.

The principle parts of a typical Houdry unit include the charge heater, three catalyst cases or three pairs of cases, air heater, gas turbine, and fractionating towers. The charge, which may consist of naphtha, kerosine, light or heavy gasoil, is passed through heat exchangers which pick up heat from the reacted vapors leaving the catalyst cases. In the charge heater the oil is heated further, depending upon the characteristic of the charge, to 700°-900° F. By means of automatically controlled valves, the heated charge is fed into the first catalyst case for 10 minutes, then switched to the second case for 10 minutes, and finally to the third case for 10 minutes. As soon as the oil is switched out of the first case and into the second, automatic controls direct heated air into the catalyst for 10 minutes. Five minutes before the 10-minute regeneration step, the case is purged and steamed. Following the regeneration, 5 minutes are required to free the case of air and flue gas. It is then ready again for the charge. The cycle is repeated in each catalyst case continuously and automatically. The time for reaction and regeneration is, of course, variable depending upon the nature of the charging stock.

The air burns off carbonaceous deposits on the catalyst and the generated flue gases then drive a gas turbine which powers the air compressor.

The heat in the regeneration step is controlled by circulation of a molten mixture of sodium nitrate and potassium nitrate through finned tubes inside the catalyst cases. To avoid injury to the catalyst, the temperature during the regeneration step is controlled to not in excess of 1000° F.

The catalyst is an aluminum hydrosilicate[2] material containing 70-80 percent silica, 10-20 percent alumina, a maximum of 10 percent other oxides, including a maximum of 3 percent ferric oxide. Other oxides such as nickel oxide up to a maximum of 10 percent may be added. About 1 percent of magnesium compounds is said to facilitate the regeneration of Houdry catalyst.[3]

All of the catalysts used in Houdry units are molded solid and are of different composition, depending upon the nature of the charging stock and other pertinent factors. The materials entering into the catalysts are mixed, molded under pressure into pellets or pills 1/6-inch in diameter, dried and baked.

Original catalyst for a Houdry unit costs about $36,000 for a plant charging 15,000 barrels of oil daily to the catalyst cases. This amounts to about $2.40 per barrel of daily plant capacity. However, it is stated that the life of the catalyst is apparently unlimited.[4]

The process operates at relatively low pressures—30 to 50 pounds per square inch, gauge. The time of contact of the vapors with the catalyst varies with the type of charge from two liquid volumes of oil to one volume of catalyst per hour. The yield also depends upon the nature of the charge. Yields of 60 to 80 percent aviation base stock with naphtha as charge, and 35 to 40 percent with gasoils as charge are possible.

A typical Houdry aviation base stock would test as follows[5]:

Gravity API	60.0
ASTM Distillation IBP	104° F.
50%	198
90%	288
E.P.	334
Acid heat	24
Octane M	77.7
Octane + 3 cc TEL	92.5
Reid vapor pressurne	7.0

Because of low yield of cracked gas, 4 to 7 percent, and the formation of no residual fuel oil, the total

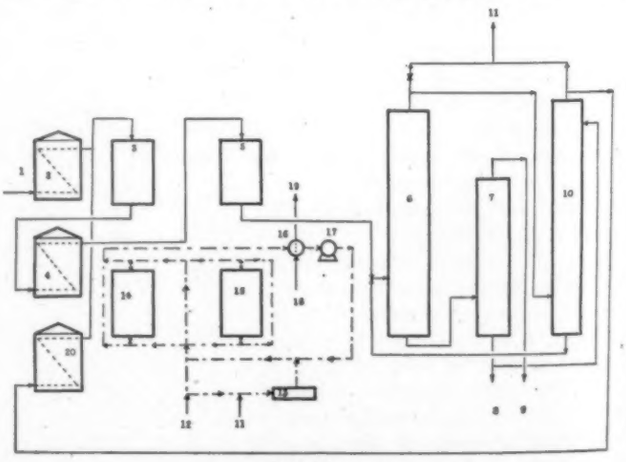


FIGURE 6
Hydroforming Process

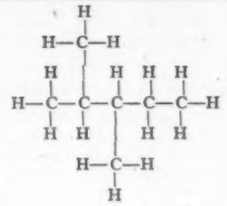
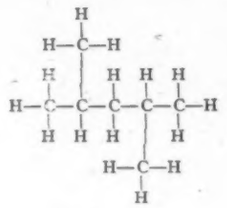
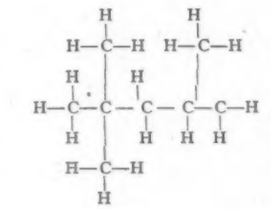
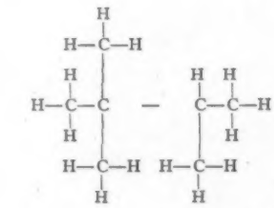
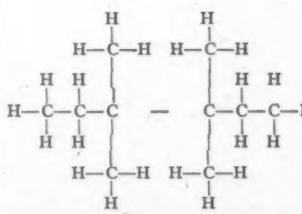
——— Catalyst Regeneration Cycle

1 Naphtha Charge; 2 Charge Heater; 3 Lead Reactor (Cracking); 4 Reheat Heater; 5 Tail Reactor; 6 Stabilizer; 7 Rerun Tower; 8 Rerun Bottoms; 9 Hydroformate; 10 Absorber; 11 Gas; 12 Air; 13 Flue Gas Generator; 14 Lead Reactor (Regenerating); 15 Tail Reactor (Regenerating); 16 Steam Generator; 17 Flue Gas Blower; 18 Boiler Feed Water; 19 Steam; 20 Recycle Gas Heater.

recovery of marketable liquid products is high, ranging from 96 to 100 percent by volume. The recycle gasoil from a typical Houdry unit may be made into a suitable furnace oil or used as charging stock for a thermal-cracking unit. Since it is predominantly aromatic or hydroaromatic in chemical structure, a high yield of gasoline can be realized from it upon thermal cracking.[6]

Houdry process aviation base gasolines contain approximately 65 percent paraffins. Since the octane is high and the response to the addition of lead is good, we would expect to find specific branched-chain hydrocarbons in the gasoline similar to the following:

TABLE 5

Molecular Formulae	Structural Formulae	Name	Molecular Weight	°F. Boiling Point	PSI @ 100° F. Vapor Pressure	Octane Number
C_7H_{16}.....		2, 3 Dimethyl Pentane	100.2	193.5° F.	2.0	94R
C_7H_{16}.....		2, 4 Dimethyl Pentane	100	177.4° F.	3.0	82M
C_8H_{18}.....		2, 2, 4 Trimethyl Pentane (iso-octane)	114.22	201.6	1.5	100 M&R
C_7H_{16}.....		2, 2, 3 Trimethyl Butane (triptane)	100.2	177.8	3.1	116 R
$C_{10}H_{22}$.....		3, 3, 4, 4 Tetramethyl Hexane	142.28	321.8	1.0	123 M

Cycloversion Catalytic Cracking

Not much comprehensive data has been published concerning the catalytic aromatization process developed and patented by Phillips Petroleum Company. The process has been given the name "Cycloversion" which indicates the type of molecular changes which are expected to take place in the operation. Largely a wartime development, having been first announced early in 1943, and because large scale catalytic-cracking facilities were then under construction, informative data concerning the process is not voluminous.[7, 8, 9, 10]

A variety of charging stocks may be used in this operation. The charge is passed through a conventional heater and heated to temperatures usually above 1000° F. with or without steam or other gas diluents. At pressures usually below 100 psi the heated charge passes through one of two catalyst chambers at up to 20 barrels per ton of catalyst per hour.

The catalyst chambers are used alternately. While one is in use the other is being regenerated. The chambers may contain one or more beds of the catalyst. Recycle material may be introduced at various levels for the purpose of controlling temperatures within the catalyst chamber. Steam is also introduced into the various beds for the purpose of preparing the catalyst for regeneration.

It is claimed that with cycloversion of naphtha-type charging stock a high-octane base stock results

containing up to 90 percent aromatic and only small percentages of olefinic compounds.

The special features claimed for the process are:

1. The simplicity of the fixed bed.
2. Simplicity which make existing equipment usable.
3. Long process periods, making complicated control equipment unnecessary.
4. Rugged, long-lived and inexpensive catalyst.
5. Precise process control.
6. Flexibility with respect to charge stock and finished products.
7. Low investment and operating costs.

A simplified flow diagram is shown in Figure 5.

The Hydroforming Process

The Hydroforming process was developed as an improvement of the conventional thermal cracking or reforming of low octane naphthas. Later catalysts were applied and the process was then known by the name "catalytic reforming." By maintaining in the reaction zone a high partial pressure of hydrogen, a much improved gasoline was produced and the process became known by the term "hydroforming."

Although the reactions involved in the process are highly complex, a few are shown here as typical.

First paraffinic naphthas are dehydrogenated to their corresponding olefinic structure. Thus, the reactions are typical of the following:

In the production of motor gasoline low-octane naphthas are converted into 75- to 85-octane number products having a very low sulfur content. In the

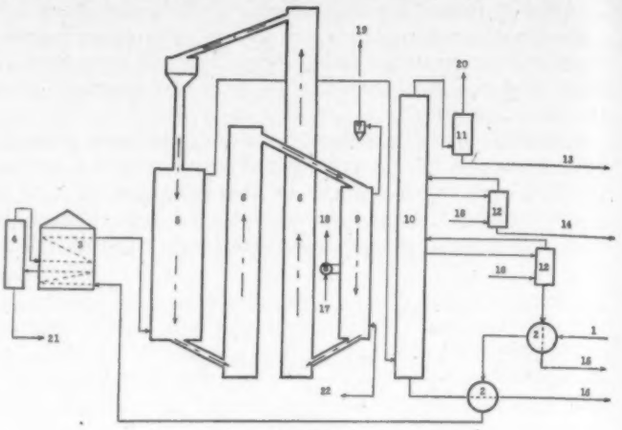
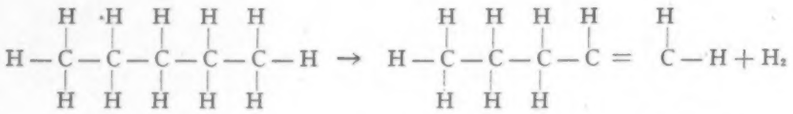


FIGURE 7

Thermofor Catalytic-Cracking Process

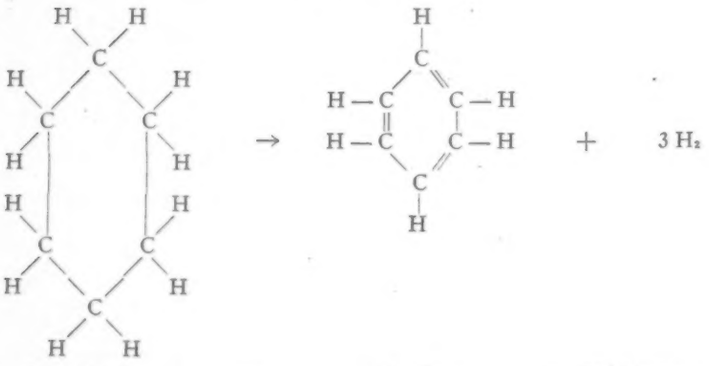
——→ Oil and Gas Flow —— — ——→ Catalyst Flow

1 Reduced Crude Charge; 2 Heat Exchangers; 3 Tube Heater; 4 Tar Separator; 5 Reactor; 6 Catalyst Elevators; 7 Fines Collector; 8 Steam Generator; 9 Thermofor Regenerator; 10 Fractionating Tower; 11 Separator; 12 Strippers; 13 Gasoline; 14 Heavy Naphtha; 15 No. 2 Fuel Oil; 16 Heavy Gasoil; 17 Boiler Feed Water; 18 Steam; 19 Flue Gas; 20 Wet Gas; 21 Residual Fuel; 22 Air.

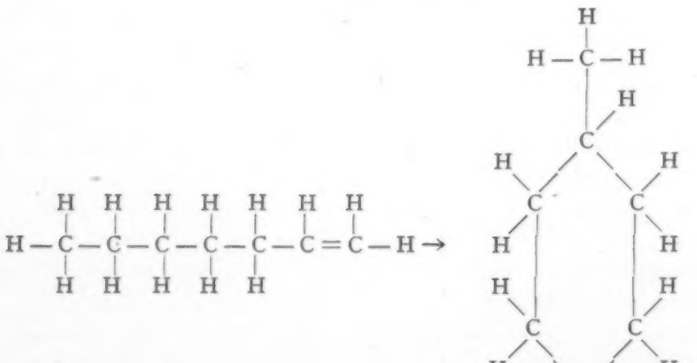


Pentane → 1—Pentene (Dehydrogenation) + Hydrogen

and



Cyclohexane → Benzene (Aromatization) + Hydrogen



1—Heptene → Methylcyclohexane (Cyclization)

presence of hydrogen, the sulfur impurities unite with the hydrogen to form hydrogen sulfide which is removed with the gas during stabilization or washed out with caustic soda solution.

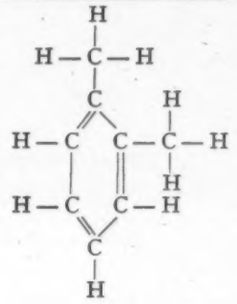
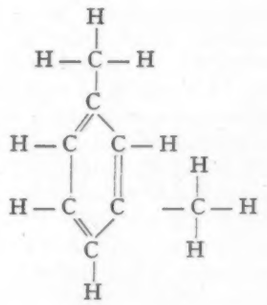
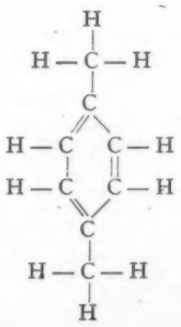
Much of the toluene used as one of the ingredients of tri-nitro-toluene (TNT) was produced during the recent war by this process. Naphtha high in normal heptane content is dehydrogenated first to heptene, then cyclized to methylcyclohexane and finally dehydrogenated to toluene. This process has sometimes been referred to as dehydrocyclization. The toluene is separated by distillation[11] and solvent-refining.

The catalysts used in hydroforming were developed by the Research Department of The M. W. Kellogg Company. See Figure 6 for simplified flow sheet. By-products of the toluene production operation are aromatic hydrocarbons such as benzene and xylenes.

12 to 1. The vaporized charge of reduced crude passes out of the heater into a flash chamber from which is removed a residual fuel. The overhead passes through a tube heater where it is heated to 750 to 1000° F. and thence to the bottom of the reactor. The vapors from the top of the reactor pass to the fractionator. The gasoline from the top of the fractionator is condensed, part of it is returned to the fractionating tower as reflux and the remainder is transferred to gasoline-blending operations. Side streams of recycle stock, furnace oil, light and heavy gasoil are taken.

The catalyst from the bottom of the reactor is transferred by an elevating mechanism to a thermofor kiln for revivication by means of heat and air. From the bottom of the kiln another elevating mechanism transfers the reactivated catalyst back to the top of the reactor to repeat the cycle.

TABLE 6

Formulae	Structural Formula	Name	Molecular Weight	°F. Boiling Point	PSI @ 100° F. Vapor Pressure	Octane Number
C_8H_{10}		Ortho-Xylene	106.2	291.2°	Less than one lb.	Over 100 R
C_8H_{10}		Meta-Xylene	106.2	278.6° F.	Less than one lb.	Over 100 R
C_8H_{10}		Para-Xylene	106.2	281.1° F.	Less than one lb.	Over 100 R

Thermofor Catalytic Cracking Process

Generally known as the TCC process, this is a moving-bed type developed by the Research and Development Division of Socony-Vacuum Oil Company.[12]

The catalyst used in most of the commercial units is produced from natural clays. It passes through the reactors countercurrent to the oil vapors which are heated in a conventional pipe heater to temperatures between 750° F. and 1000° F. and at pressures of 10-25 psi. The catalyst-to-oil ratio is on the order of

A simplified flow diagram is shown in Figure 7.

Fluid Catalytic Cracking Process

A fluid-bed type of cracking process was announced early in 1941.[13] The equipment necessary for the process is similar to that required for Thermofor Catalytic Cracking. The chemistry involved in the operation is essentially the same as that discussed in the other catalytic cracking methods discussed previously. Splitting of molecules, aromatization, poly-

merization, isomerization and other reactions are known to take place.

In the Fluid Catalyst Process, the gasoil charge is heated in a conventional tube still heater to a temperature sufficient to vaporize the entire charge—800 to 1000° F. Very finely divided catalyst, so fine that most of it passes a 300 mesh screen, is introduced into the vaporized oil. Vapors and catalyst powder are mixed by passing them through perforated plates as they enter the bottom of the reactor. Reactions take place as the mixture passes upward through the reactor. From the top of the reaction chamber, the mixture passes into a "cyclone" separator so constructed to facilitate the accumulation of the powdered catalyst in its cone-shaped bottom. The vapors pass from the cyclone separator to conventional fractionating equipment.

From the bottom of the cyclone separator the spent catalyst passes into the regenerator where an air-fluegas mixture burns off carbonaceous deposits. Additional catalyst is recovered from the mixture out of the top of the regenerator as it passes through a Cottrell precipitator, the bottoms from the Cottrell precipitator join the accumulation of catalyst in the regenerator.

The following advantages are claimed for the process[14]:

1. Catalyst recovery is simplified since 0.5 to 1.0% of the catalyst is all that usually must be recovered from the vapor stream.
2. Level of solids in the reactor can be set at will.
3. Height of the unit supporting structure is less.
4. External catalyst hoppers are not needed.
5. At least part of the catalyst-recovery equipment may be placed within the reaction vessels instead of outside.

A simplified flow diagram is shown in Figure 8.

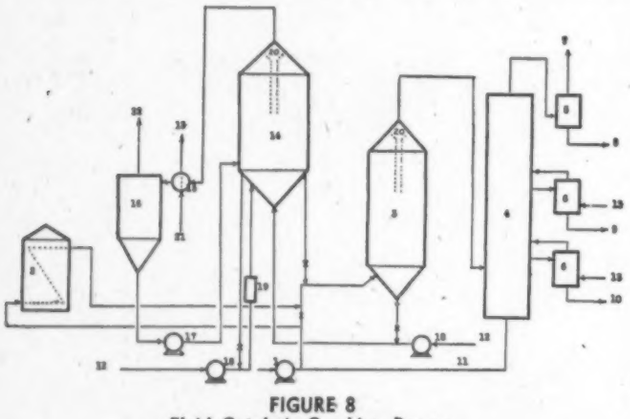


FIGURE 8
Fluid Catalytic-Cracking Process

1 Charge Pump; 2 Charge Heater; 3 Reactor; 4 Fractionator; 5 Separator; 6 Strippers; 7 Gas; 8 Gasoline; 9 Heating Oil; 10 Gasoil; 11 Recycle; 12 Air; 13 Steam; 14 Regenerator; 15 Steam Generator; 16 Cottrell Precipitator; 17 Catalyst Pump; 18 Air Blower; 19 Catalyst Cooler; 20 Cyclone Separator; 21 Boiler Feed Water; 22 Vent.

Suspensoid Catalytic Cracking Process

The Suspensoid process developed by Imperial Oil Ltd. utilizes finely divided clay catalyst which is injected as an oil-clay slurry into the oil charging stock going to the charge heater. The mixture is heated to 1000-1100° F. temperature at 150 to 800 psi pressure. Specially designed heaters, with large inside diameter tubes and streamlined return bends (not indicated in Figure 9) are such as to prevent excessive erosion and settling out of the catalyst.

The heated charge and slurry passes into a fractionating tower from which tar-catalyst mixture is taken at the bottom. Side cuts and recycle are taken from the tower at various levels and gasoline is condensed from the top of the tower. The tar-catalyst mixture from the combination reactor and fractionator bottom passes through a specially designed filter which recovers a tar filtrate free of catalyst and a filter cake of spent catalyst which may be discarded or recovered in a clay burner for reuse as catalyst.

Yields are comparable to thermal cracking, but octane and lead susceptibility are appreciably better

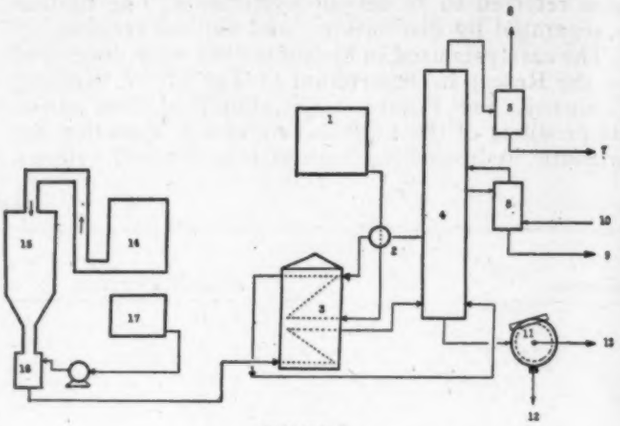


FIGURE 9
Suspensoid Catalytic-Cracking Process

1 Fresh Feed; 2 Heat Exchanger; 3 Tube Heater; 4 Combination Reactor and Fractionator; 5 Separator; 6 Gas; 7 Gasoline; 8 Stripper; 9 Heating Oil; 10 Steam; 11 Rotary Filter; 12 Spent Catalyst; 13 Tar Oil; 14 Catalyst Storage; 15 Catalyst Hopper; 16 Slurry Mixer; 17 Slurry Oil.

than gasoline from thermal cracking. A high yield of unsaturated gases are produced which make good charging stock for polymerization or alkylation operations. A simplified flow diagram of the Suspensoid Process is represented by Figure 9.

These are the more important catalytic cracking operations which are in use today. Their development and use during the recent war made possible the production of thousands of barrels per day of base stock for 100-octane aviation fuel. Many improvements have been made in recent months and others are being announced frequently. Many of the recent developments are in the field of improved catalysts. Most if not all of the units built to speed victory are being used with minor modifications to produce automotive fuel of high quality.

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Samples required for laboratory analyses have been reduced from gallons to drops

Fingerprinting Hydrocarbons and Compounds

FOR centuries, men searched in vain for some uniform and infallible method of establishing personal identity. Each proposal was explored and rejected until, in our own time, an answer was found right on the seachers' fingertips. The learned gentlemen discovered, to their astonishment and delight, that the tiny arches, loops, and whorls in their fingerprints were different from those of any other person. Although prints are grouped into similar general patterns, no two persons have exactly the same prints. Oddly enough — and this made it perfect — tests proved that fingerprints remain unchanged from cradle to grave.

THIS article from the March-April "Humble Way" was written to acquaint those with limited technical knowledge with the accomplishments of the newer instruments of the laboratory. It is being reproduced for the reason that many readers of Petroleum Refiner have neither the background nor the necessity for knowing how these instruments operate. They are, however, interested in what these instruments can do.

Information for preparation of the manuscript came out of the new Physical Measurements Laboratory of Humble Oil & Refining Company, Baytown, Texas.

In industry, too, men of science searched diligently for surer, faster methods of determining the identity of unknown compounds. The quest was not only for faster and more accurate means of identification, but also for ways to identify those materials which previously had resisted all known means of analysis.

In the last five years, physicists have successfully combined their knowledge of electronics and spectroscopy (that branch of physics which deals with the innermost properties of molecules) to develop and perfect instruments which, in effect, take an unknown sample's composite fingerprint. These new processes have unlocked doors long closed to the petroleum and chemical industries, in whose laboratories it is now possible to analyze oils and many other complex chemicals in a fraction of the time formerly required. More than that, it has literally brought to light several ways of analyzing compounds previously untouchable by any method. Myriad combinations of hydrogen and carbon making up crude petroleum and its components may be sorted out and identified as quickly and accurately as a stranger is identified by his fingerprints. Indeed, since the character and identity of the mixture under analysis are established through markings made on photographic film by

a recording device, the fingerprinting analogy is singularly appropriate.

Although similar in certain general respects, these spectroscopic and electronic instruments vary widely in design and application. *Absorption spectrometers,* for instance, analyze certain oils by the amount of ultraviolet or infrared light they absorb. Unabsorbed light passing on through the sample, is measured and recorded in terms of transmitted energy. The amount of energy absorbed and the wave length at which it is absorbed determine the sample's composition. If the sample is a mixture of compounds, each will be identified by the position at which its absorption curve appears on a chart record. From the peaks and valleys drawn by the measuring instrument on this paper chart, operators may also determine the concentration, as well as the identity, of each type of oil in the mixture.

Another instrument, called the *mass spectrometer,* includes an electron gun which shoots negative electrical charges away from the molecules in a gas sample, leaving them with excess of positive charge. These positively charged masses are set in motion and move in curves of varying radii, the radius of curvature depending on the weight of each mass. The spectra of these masses are scanned, one at a time, across a receiving device which measures the amount of electrical current in each mass group. The different gases represented by these mixture spectra are thus distinguished by the amount of current recorded by the instrument at definite positions on a chart roll of photographic paper.

Still another instrument, the *emission spectrograph,* is used to determine elements present in a mixture by exposing a photographic film to the sample's light spectrum when the sample is burned at 5000° C. in an electric arc. By comparison with a master film, the elemental composition of the sample may be determined.

At Humble Oil & Refining Company's Baytown refinery, these and many other related instruments have been brought together in a new air-conditioned Physical Measurements Laboratory. The machines themselves resemble hybrid crosses between a modern radio station and something from a fantastic Jules Verne novel. Besides those already mentioned, there are others bearing such awesome names as *polarographs, flame photometers,* and *X-ray analyzers.* They are complicated in design, but are surprisingly easy to operate.

Before any attempt is made to discuss these instruments in detail, let us review some elementary physics.

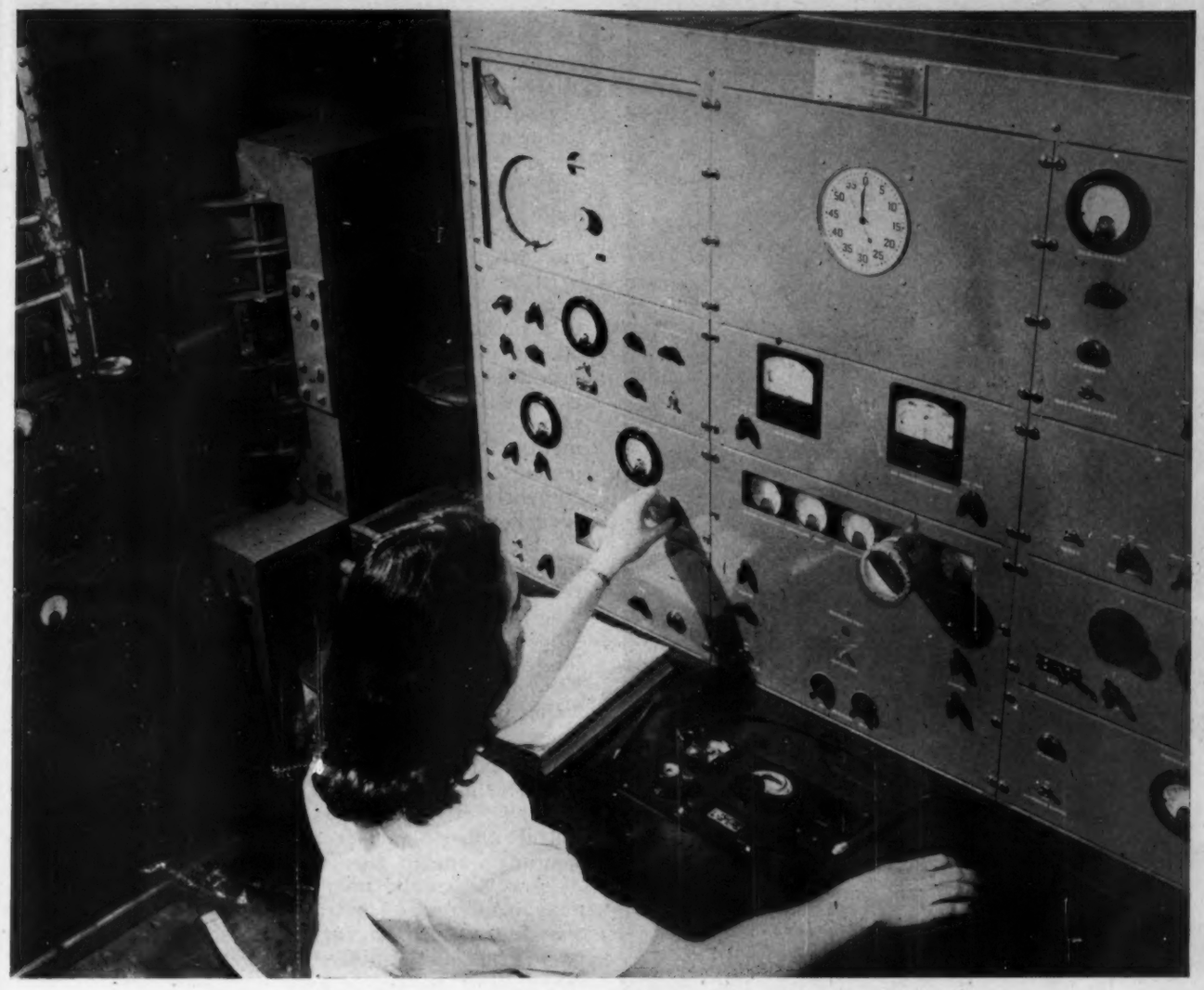
Everyone is familiar with the gaily-colored *spectrum* in a rainbow as sunlight is dispersed, or bent and separated, by passing through water particles. The rainbow's beautiful colors are caused by different *wave lengths* of light. But there is more to this spectrum than meets the eye; not all light waves are visible in the rainbow. Infrared waves, for instance, are too long to be seen by the human eye; ultraviolet waves too short. It is on these invisible waves that many spectroscopic instruments depend for their operation.

Take the *infrared spectrometer,* for example. Source of light for this instrument is a glowing carborundum rod, electrically heated to 1000 degrees, at which temperature the rod emits light rich in infrared waves. The extent to which samples of unknown oils absorb this light determines their composition.

Only one fifth of a cubic centimeter of oil—about two drops from a household medicine dropper—is required to make an analysis with the infrared spectrometer. So small is the sample that it must be injected with a hypodermic needle. The cell, or sample holder, consists of two plates of compressed and polished rock salt with barely enough opening between to hold the sample.

When the cell is filled and in position, light from

Absorption spectrometers analyze compounds by the amount of ultraviolet or infrared light they absorb.



Control of mass spectrometer operations is with dials and switches on a panel board.

the carborundum rod is directed through the sample. Obeying spectroscopic laws, the sample absorbs some of the light and allows the rest to pass on through to an arrangement of rock salt prisms and polished mirrors whose purpose is to sift out and purify the infrared light. Different wave lengths can be selected by changing the position of the mirrors and prisms.

The sifted and purified light is allowed to shine on a thermopile, or highly sensitive device for measuring heat (infrared light, of course, contains heat energy). The impulse from this thermopile, translating heat into electrical energy, is directed to a galvanometer. This is a device so delicately balanced that the slightest electrical impulse will unbalance it, causing it to swing to one side or the other. The extent to which the galvanometer is unbalanced is detected by a photoelectric cell, or so-called "electric-eye," which relays the amount of energy causing the deflection to an amplifying system. Magnified some 33,000 times by the amplyfying mechanism, electrical energy which originated at the thermopile is now measurable in millivolts (1000 millivolts to a volt) and is recorded on the paper chart of a temperature instrument. From positions of lines drawn on this chart, it is possible to identify the material or materials in the unknown sample.

The *ultraviolet spectrometer* acts on exactly the same principle as the infrared, except that it uses wave lengths below, instead of above, the range of vision. Ultraviolet light source is a hydrogen discharge tube; quartz, instead of rock salt, is used in prisms and cells. Both instruments must be calibrated, or pre-checked, on pure compounds before analyses can be run on unknowns, and a "black determination" is taken before each analysis, making use of a non-absorbing substance which will "zero" the instrument.

Now to the *mass spectrometer.*

This, strictly speaking, is an electrical and electronic instrument. It operates on gases, rather than liquids or solids. So precise is the mass spectrometer that it deals in molecules, or molecular masses. A thimbleful of gas at atmospheric pressure provides enough sample for ten analyses. Gas samples are put under high vacuum and passed continuously to an *ionization chamber* where molecules of the gas are bombarded with low-speed electrons. This electron artillery knocks off negative electrical charges from each molecule, leaving it positively charged.

The masses are formed in an electrostatic field and are set into motion immediately; a movement thus far is in a straight line. Next, they are passed transversely through on electromagnetic field, which sep-

The emission spectrograph literally takes the picture of elements burning in an electric arc.

arates the different masses according to weight and changes their motion from a straight line to a curve. The lighter masses travel in short-radii curves; heavier masses have travel curvatures with longer radii.

Since only one mass can be measured at a time, the various masses in the spectra are scanned across a narrow slit, one at a time, by changing the voltage of the electrostatic field. As each group of masses crosses the slit, the positive charge is caught on a collector pltae, thus giving a definite amount of electrical current. Currents caused by impingement of the electrical charges of the various masses on the collector plate are amplified about 1000 times and sent to a galvanometer and recording device. Variations in current are recorded as hills and valleys on the sheet of photographic paper in the recorder. The positions at which hills appear identify hydrocarbons of particular mass weight; height of each peak establishes the concentration of those masses in the gas mixture. Since several compounds may produce the same mass, it is necessary to separate several masses in order to identify two or three compounds of the same original weight.

That brings us up to the *emission spectrograph.*

The emission spectrograph is designed to detect the presence and measure the concentration of elements, rather than compounds, in solids and solutions. Operation of the instrument depends upon the light-emitting characteristics of elements in the test specimen when it is placed in a high-temperature arc.

Light from the arc passes through a narrow slit to a diffraction grating and is returned from there to a photographic film. An image of the slit occurs on the film at each wave length for which light is produced in the source. After development, the film is placed in a densitometer in which there is a master plate containing characteristic lines of all the elements. The film of the unknown substance is projected on a screen alongside the master film for comparison. The positions of the various lines and their comparative densities indicate various elements in the sample. Densities, read directly from an ammeter in a phototube amplifier circuit, indicate the relative amounts of those elements in the mixture. The instrument is equipped for photographing emission spectra in both the visible and ultraviolet wave length ranges.

So much for the operation of these instruments. What about their past, present, and possible future uses?

A great many advantages have already been derived from their applications at Baytown. An ultraviolet spectrimeter installed on the feed line at the Butyl rubber plant keeps a running record of the percent isoprene in the feed stream. The accuracy of this work can be imagined when it is pointed out that isoprene concentration must be controlled at *one half of one percent.* Other spectroscopic instruments had distinguished war records; some of them were used to run quick, complete, and accurate analyses on streams leading to and from the isomerization unit, thereby making it possible to maintain maximum production of the isobutane so urgently needed at that time in the manufacture of aviation alkylate. Still others give fast and extremely accurate determinations of the percent isobutylene in the total butane cut drawn from the catalytic cracking units.

Presently, analyses at the Physical Measurements Laboratory are saving valuable time by clipping hours off the time formerly required to run certain tests. Since the instruments require only very small samples, it is now possible to maintain thorough checks on the work of small pilot units doing research work. Both infrared and ultraviolet spectrometers are being used to control practically all operations at the govenment-owned, Humble-operated butadiene plant at Baytown, and a continuous ultraviolet recorder is used to follow operations in the final extraction unit at that plant.

Future applications of spectroscopic instruments appear unlimited. Preparations are already being made to install suitable models on plant equipment for continuous determination of product quality.

Considering what has already been done during the last five years, it seems within the bounds of reason to say that further application of these and other physical methods will continue to make industry's analytical tasks easier in the years to come.

Physical Chemistry of Lubricating Oils

Part II—VISCOSITY

A. BONDI, International Lubricant Corporation, New Orleans, Louisiana

IN THIS paper an attempt has been made to present as complete a picture of the more important aspects of lubricating-oil viscosity and viscosimetry as is practicable at the present moment.

The dependence of viscosity on the variables of state: temperature, pressure, and concentration, is discussed from the points of view of the physico-chemist, as well as the lubrication engineer. The relationship between the temperature, pressure and blending coefficients of viscosity and the chemical composition of lubricants is interpreted in terms of the Eyring theory of flow, a brief outline of which is given in Section III. 2.

A section on anomalous flow of lubricating oils: at low temperature, or due to temperature gradients within the fast-flowing oil films, or due to the presence of high-molecular-weight additives which have now gained a place of prominence in many important applications of lubricating oils, concludes the strictly physico-chemical portion of the paper.

The last section (III. 5) deals with the application of our increased knowledge about the behaviour of lubricating oil under the influence of high velocity gradients and high specific pressure to the calculation and lubrication of journal bearings.

III. 1 Definitions

THE viscosity of a lubricating oil is its most characteristic property, determining, as it does, its ability to lubricate. The numerical value of the viscosity (at the temperature of operation) is the only one of the many physical data of a modern lubricating-oil analysis sheet which enters directly into engineering calculations. A short paragraph at the end of this article will show how the viscosity enters into bearing-performance calculations. But, first, we shall see what viscosity is, and how it depends on temperature, pressure and chemical composition.

In 1687 Newton defined the resistance of a liquid to flow, due to "lack of slipperiness," by the fundamental equation

$$P = 2\eta\dot{e} \qquad (1)$$

where. P = the shear stress (force per unit area),
$\dot{e}$ = the change in velocity with distance from the wall (Figure 8) (velocity gradient or strain rate).
η = the viscosity-coefficient (today usually called "viscosity").

Expressed in ordinary units, viscosity (one poise) is the resistance offered by a layer of liquid 1 cubic meter thick, letting a plate of 1 square cubic meter area under a force of 1 gram slide over another at a rate of 1 cubic meter per second. This differential equation was about 150 years later solved by Hagen and Poiseuille for the case of liquid flowing through capillary-tubes, giving

$$\frac{Q}{t} = \frac{\Delta P \pi R^4}{8\eta l} \qquad (2)$$

the familiar Hagen-Poiseuille equation, where:

$\frac{Q}{t}$ = volume discharged per unit of time

ΔP = pressure drop across the capillary of radius R and length l.

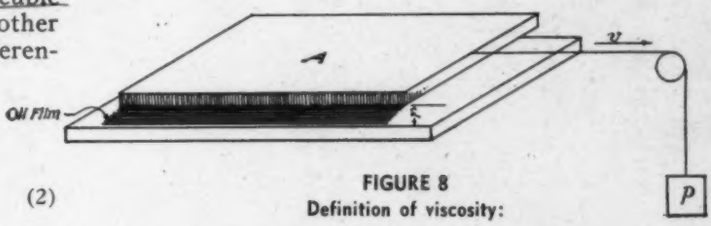


FIGURE 8
Definition of viscosity:

$$\eta = \frac{P}{A}\left(\frac{dv}{dr}\right)^{-1}$$

v = Velocity
A = Area

While Poiseuille's viscosimeter was still a somewhat awkward instrument, Wi. Ostwald devised about 10 years later a simple glass "viscosity-pipette" which is still today the most widely used piece of laboratory equipment.* The simplicity of this apparatus (Figure 9) and its operation, as well as the readily grasped significance of results obtained in absolute viscosity units, make it hard to understand why the "conventional" viscosimeters have ever found entrance in the petroleum industry. The design of these "machines" is awkward and shows more semblance to a kitchen utensil than to a piece of laboratory equipment. The principal shortcoming of all three conventional viscosimeters is—as has been amply discussed elsewhere [24,25]—the shortness of the capillary, such that at low viscosities (<.5 Poise) the uniform velocity distribution, on the assumption of which eq. (2) is based, is not at all or only for a small portion of the capillary length attained. While there is hardly a laboratory which uses Saybolt, Redwood or Engler instruments today, due to the mental inertia of commerce, the results obtained with "absolute" viscosimeters are still very often converted into the old units. In the following discussion only absolute units (See Table 9) will be used.

*ASTM Standard D445-42T.

III. 2 The Viscosity-Temperature Function

a. Empirical expressions

The comparatively strong change of viscosity of

lubricating oils with temperature has long been known as one of their most troublesome characteristics. Especially, the fact that lubricating oils of the same viscosity at 210°F. may differ in viscosity at 100°F. by several 100 percent made it desirable to introduce the rate of change of viscosity with temperature as a quality criterion. Unfortunately, our knowledge of the physics of the liquid state was then not sufficiently far advanced to offer to the petroleum industry a theoretically sound expression for the viscosity-temperature function. But, since the motorist who could not start his car on a cold morning was certainly not willing to wait for any further developments in physics, nor were the marketers who did not want to lose this motorist's account, an empirical way out had to be found. At the same time, (1928-9) two fundamentally different methods of characterization for the viscosity-temperature behavior of lubricating oils were offered to the oil world: The Viscosity-Index by Dean and Davis[28] and the constant "m" by C. Walther[29]. Due to its simplicity of approach and speedy advertising exploitation the Viscosity-Index (V.I.) was readily adopted

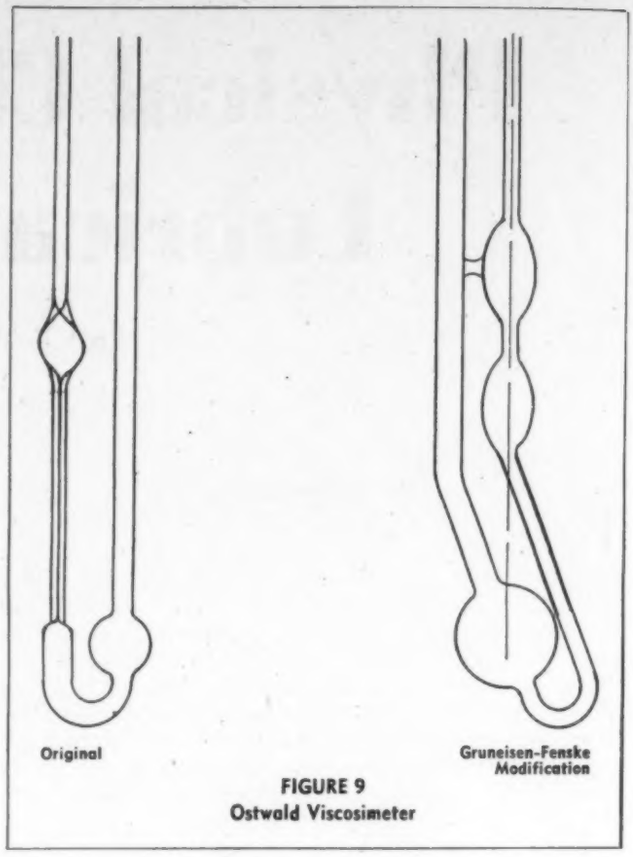


FIGURE 9
Ostwald Viscosimeter

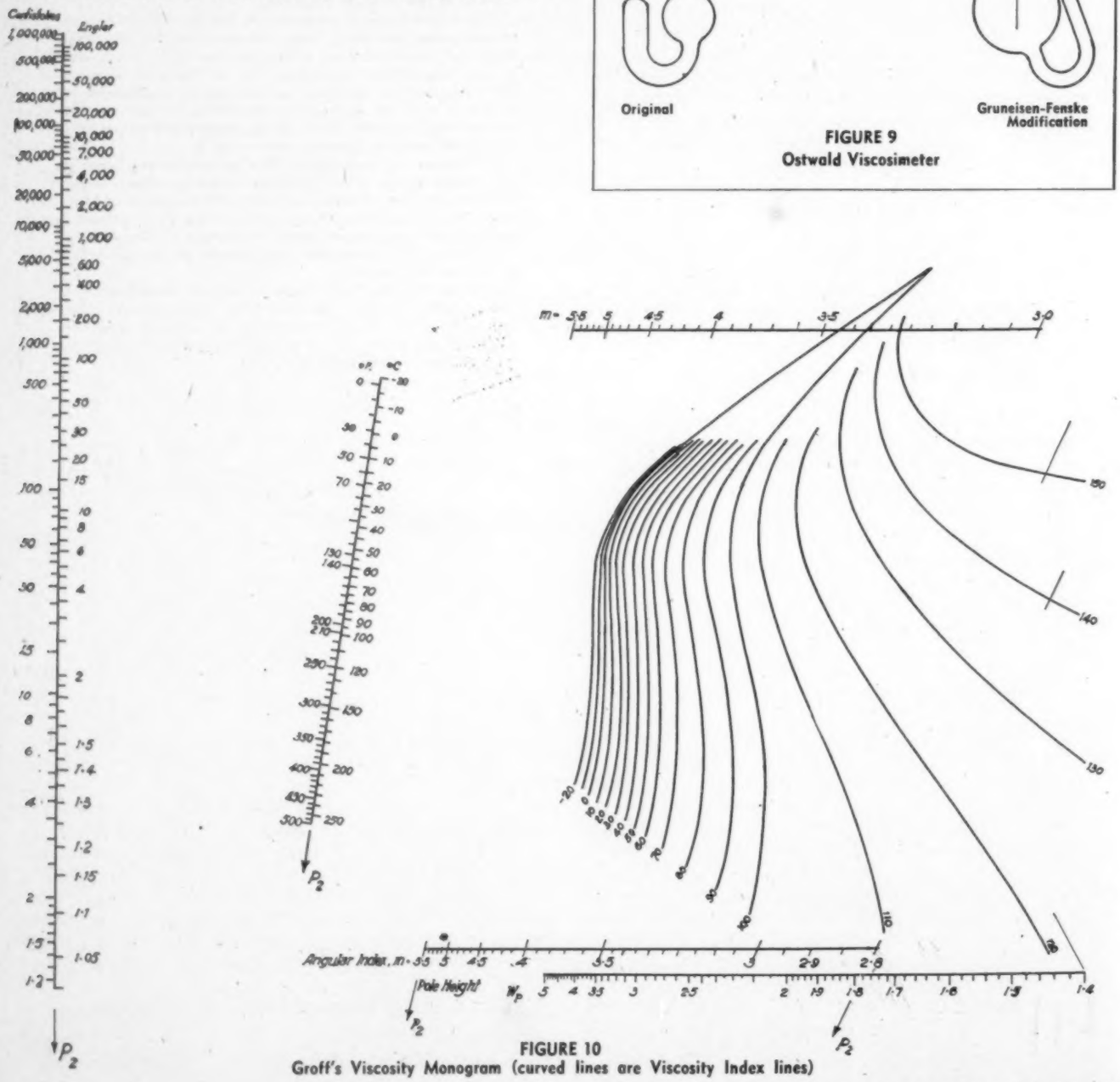


FIGURE 10
Groff's Viscosity Monogram (curved lines are Viscosity Index lines)

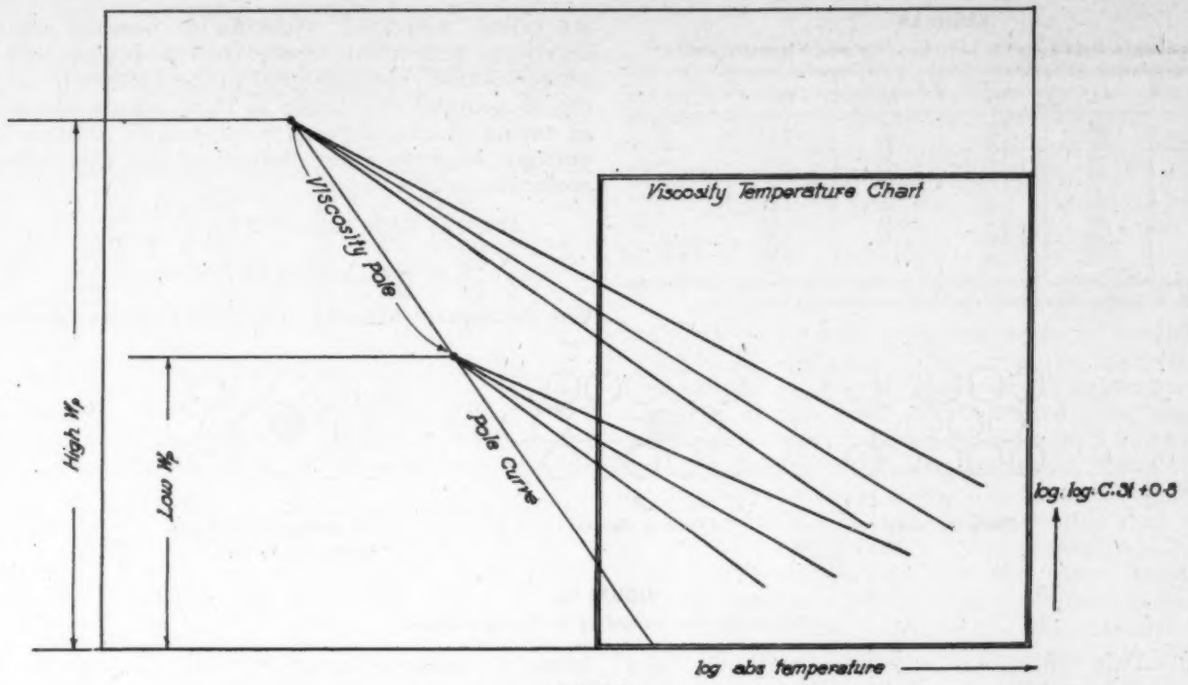


FIGURE 11

by the American petroleum industry. As is well known, the V.I. is determined by the formula:

$$V.I. = \frac{L-U}{L-H} \times 100, \text{ where}$$

U = viscosity of oil in question @ 100° F.
L = viscosity @ 100° F. of Gulf Coastal oil, having the same viscosity @ 210° F. as oil in question.
H = viscosity @ 100° F. of Pennsylvania oil of the same viscosity @ 210° F. as oil in question.

The rather arbitrary choice of reference substances (series of "typical" Coastal and Pennsylvania lubricating oils) and the empirical nature of the whole calculating procedure is brought out by the peculiar form of the curves on Figure 10. But, only with the recent advent of oils (mainly synthetic) which fall completely out of the range of the viscosity-index system have the shortcomings of the V.I. system become obvious[30] and recourse is taken to Walther's method of evaluation by specifying the slope of the viscosity curve on the A.S.T.M.—Viscosity-Temperature Chart—for that is essentially the meaning of the constant "m" referred to above. The A.S.T.M. chart (and the Walther-Ubbelohde chart) have as coordinates: W = log log (cSt + 0 · 8) and log (abs-temp.). The slope of a viscosity line on these charts is therefore given by

$$m = \frac{W_1 - W_2}{\log T_2 - \log T_1} \qquad (4)$$

TABLE 13

Values of W_p for a Few Polymer Homologous Series

Series		Fraction 1	2	3	4	5†
Blown Rape seed oil.....Stokes @ 50°C		.59	3.36	6.34	26.0	
(While blowing same) Wp.....		1.35	1.38	1.40	1.36	
Fractions of Synthol Lube Oil.....Wp		1.76	1.75	1.55	1.60	1.98
Polyisobutylenes.....Poises @ 50°C		4.32	29.5	130	300	6,250
	Wp	2.05	1.90	1.84	1.68	1.43
Polyethyleneglycols*.....Poises @ 50°C		.13	.16	.28	.39	.76
	Wp	1.02	.91	1.12	1.00	1.03
Poly Alkylsilicones*.....Poises @ 50°C		.66	1.29	2.25	3.20	5.80
	Wp	.68	.68	.60	.69	.76

* Wp for these substances had to be calculated by means of eq. 17 of ref. (31 b), since their "viscosity pole" does not fall on the usual "pole curve."

Later on Ubbelohde and Walther[31] made the interesting observation that within any one group of oils the value of *m* decreases with increasing viscosity-range of each oil, such that the curves of all Pennsylvania oils, for instance, meet in one point (pole) outside the chart (Figure 11). The value W_p of this point was called the Viscosity-Pole-Height. Not for all crude oils could W_p be found to stay constant from fraction to fraction (see Table 12). But, for quite a few groups of oils and polymer homologous series of substances W_p is reasonably constant. (See Table 13). We may have to assume the average chemical composition to vary from fraction to fraction in those crude oils where W_p is not a constant for all fractions. The value of W_p is most easily determined graphically either on the new viscosity-temperature chart by Ubbelohde and Kemmler[32] or on the viscosity nomogram by Groff.[33] The Viscosity-Pole-Height W_p has in many countries taken the place of the viscosity index. The two expressions—W_p and V.I.—however, are not interconvertible. An *approximate* relationship, which is valid for oils ranging from SAE 10 to SAE 60, and V.I. 0 to 100, has been presented in Table 14. Although, as Table 13 shows, the phenomenon of the viscosity pole must be more than a mere freak, no theoretical explanation has as yet been offered. The straight-line relationship between the double logarithm the kinematic viscosity (in centistokes) and the logarithm of the absolute temperature on which both the A.S.T.M. and Ubbelohde's charts are based, is very difficult to understand. As a double logarithmic relationship, its validity is dependent on the scale of the units chosen (centistokes), and it will indeed be found that stokes or millistokes or Reyns (lb., ft., sec.-units) will give neither straight lines nor viscosity poles.[34] A natural law is always valid independent of the units in which it is expressed. We must, therefore, assume that the physical law underlying this empirical relationship contains the double logarithm of the ratio of the viscosity at the temperature under consideration to some "critical" viscosity (not at the critical temperature) which is of the order of 100th of the viscosity unit

TABLE 14

Approximate Relationship Between Wp and Viscosity Index*

Wp.	V.I.	Wp.	V.I.	Wp.	V.I.
1.80	102	2.30	73	3.1	26
1.85	100	2.40	67	3.2	20
1.90	97	2.50	61	3.3	14
1.95	93	2.60	55	3.4	8
2.00	91	2.70	49	3.5	2
2.05	88	2.80	43	3.55	0
2.10	85	2.90	38	3.60	−4
2.15	82	3.00	32	3.70	−10
2.20	79	...	...	3.80	−16

* From E. H. Kadmer, Schmierstoffe and Maschinenschmierung, Berlin, 1941.

chosen. This possible connection with viscosity theory will be published elsewhere. Numerous other empirical viscosity-temperature relationships have been proposed[35] but none as simple as the one just described, and the only thing that can justify the use of empirical rules is simplicity.

b. *Theory of Viscosity*

Many theories of viscosity have been proposed during the past three decades. The most successful and self-consistent of these is the theory which was originated by H. Eyring[36] and his co-workers. This theory will form the basis for the discussion of the temperature-pressure and concentration functions of the viscosity of lubricating oils.

The following picture was developed: A liquid consists of fairly closely packed molecules. The empty space (free volume) between them is not enough to permit free movement of one molecule past the other. In order that one molecule may move (Figure 12) its neighbors have to get out of its way, i.e., form a hole. Then the "activated" molecule moves into the hole. Only a small number of molecules have sufficient extra energy to overcome the attractive forces of their neighbors and go through the indicated process of motion. These few molecules are called "activated" (just as in chemical reaction kinetics), and their concentration is—as will be seen—inversely proportional to the kinematic viscosity of a liquid. Viscosity is thus simply expressed in terms of the difference in energy content and entropy between these activated and the ordinary molecules of the liquid:

$$\Delta F\ddagger = -RT \ln \frac{C\ddagger}{C} = RT \ln \left(\frac{V\eta}{Nh}\right) \quad (5)$$

$$\eta = \frac{Nh}{V} e^{\Delta F\ddagger/RT} = \frac{Nh}{V} e^{-\Delta S\ddagger} e^{\Delta H\ddagger/RT} \quad (6)$$

(For the complete derivation of these formulae see reference[36].)

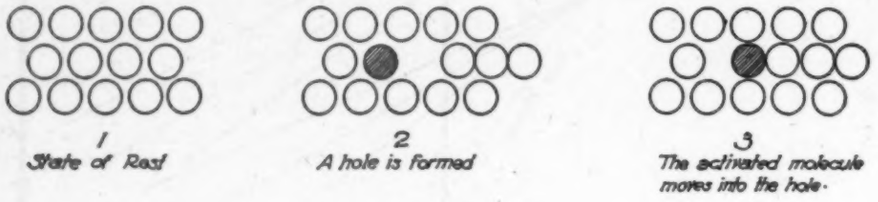


FIGURE 12

Process of flow according to Eyring's theory.

where: η = dynamic viscosity, V = Molar volume, R = Gas-constant, T = abs. temperature, N = Avogadro-number, h = Planck's constant, C‡, C = concentration of activated and normal molecules respectively, $\Delta F\ddagger$ = Free energy of activation, $\Delta H\ddagger$ = Heat of activation, $\Delta S\ddagger$ = Entropy of activation.

We see that the absolute magnitude of viscosity is a function of the relative concentration of activated molecules, while the temperature dependence of viscosity is determined by the amount of energy ($\Delta H\ddagger$) which a molecule has to have in order to move. The magnitude of $\Delta S\ddagger$ is a measure of the degree of disorder produced in the rearrangement of molecules within a liquid by the process of motion. The $\Delta H\ddagger$ and $\Delta S\ddagger$ of simple liquids, such as benzene, pentane, etc., change comparatively little with temperature. For such complicated molecules as are present in lubricating oils $\Delta H\ddagger$ and $\Delta S\ddagger$ are themselves very strongly temperature dependent, indicating that motion of such liquids involves not only overcoming of the attractive forces of the molecules upon each other, but also a certain amount of deformation of the activated molecule itself. This explains the high viscosity of such compounds. Sometimes, as in the case of castor oil, the fairly strong chemical bonds between OH-groups have also to be broken in order to make the liquid move, accounting for its high viscosity. The difference between the $\Delta H\ddagger$ of castor oil and of tri-olein is in fact equal to the known strength of this so-called "hydrogen-bond," i.e. ~ 6 kcal.

In the following tables a few typical $\Delta F\ddagger$, $\Delta H\ddagger$, and $\Delta S\ddagger$ values of lubricating oils, and such synthetic hydrocarbons as are presumably present in lubricating oils, are assembled.

Regarding the relationship between chemical constitution and viscosity and its temperature coefficient, the following conclusions can be drawn from the data presented.[37]

1. While the viscosity (especially at lower temperatures) increases exponentially with the molecular weight—within any one group of compounds—$\Delta H\ddagger$ increases linearly with the molecular weight, such that $\Delta H\ddagger/_M$, the heat of activation per gram (at a standardized temperature), could well be used as a group constant both for oils and pure compounds.

2. Keeping the molecular weight constant and

TABLE 15

Chemical Structure and Viscosity of Hydrocarbons

Hydrocarbon	M	μ 100° F. Stokes	△H‡ Kcal/Mole	△H‡/M cal/g	Wp	V.-J.
I Naphthenes						
11—Decalin Heneicosane	432	.457	6.31	14.6	1.9	95
1.1—Dicyclohexylethylnonane	398	.335	5.13	17.8	2.05	70
Tri-cylohexhylethyl methane	346	1.70	16.30	46.8	4.20	—5
1—Cyclohexyleicosane	365	.165	4.39	12.1	....	176
II Aromatics						
1—Phenyleicosane	359	.115	3.92	10.9	....	180
Tri-Ethylbenzene-methane	329	.257	6.03	18.3	3.0	—15
1.1 Di-p-tolyl-dodecane	351	.263	5.86	16.7	2.18	28
Tri-hexylnaphthalene	380	...	....	....	1.78	98
III Isoparaffines						
11-h-Decylheneicosane	436	.151	4.50	10.3	....	149
7, 12 Dimethyl, 9, 10 Dihexyl octadecane.	450	.20	5.15	11.4	1.45	...
7, 16 Dimethyl, 9, 11, 12, 14 Tetrahexyldocosane	675	.85	7.20	10.7	2.50	77

TABLE 16

The Effect of Hydrogenation of Aromatic Compounds and of Aromatic (Solvent-Extract) Petroleum Fractions on their Viscosity and Viscosity-Temperature Function

Substance	M	η 38° C. Stokes	$\Delta\overline{H}\ddagger$ Kcal	$\Delta\overline{H}\ddagger$/M cal/g	V.I.
	328	.26	7.20	22.0	—15
	347	1.70	10.60	30.5	—5
1, 1-Diphenyltetradecane	350	.186	6.07	17.3	.....
1, 1-Dicyclohexyltetradecane	362	.364	7.25	20.0	.....
2,-Octadecyl-napthalin	384	.229	6.70	17.4	.....
2,-Octadecyl-tetralin	388	.237	6.85	17.6	.....
2,-Octadecyl-Decain	394	.308	7.25	16.3	.....
2,-Docosyl-naphthalin	436	.338	6.67	15.2	.....
2,-Docosyl-tetralin	440	.376	7.05	16.0	.....
2,-Docosyl-octalin	444	.443	7.25	16.3	.....
Extract Fractions:					
B-12	308	12.0	16.60	54	—560
B-12, hydrogenated	314	1.37	11.00	35	—143
C-7	318	70.3	20.7	65	—1340
C-7, hydrogenated	329	3.67	13.3	40.5	—254
C-33	390	1.01	9.52	24.4	8
C-33, hydrogenated	394	.90	9.05	22.9	37

varying the constitution of the molecule results in: Increase of viscosity and $\Delta H\ddagger$ (as well as $\Delta S\ddagger$) with increasing spherical symmetry (in all three space coordinates!) of the molecule. This effect can be had either by multiple branching, or the inclusion of cyclic systems in the molecule. In the latter case $\Delta H\ddagger$ and $\Delta S\ddagger$ increase in the order cyclopentane < benzene < cyclohexane < condensed ring systems. Altogether the geometry of a hydrocarbon molecule is of much greater effect on η and $\Delta H\ddagger$ than the distribution of chemical bonds.

3. The physical properties, especially η and $\Delta H\ddagger$ of long-chain alkylated (one- and possibly two-) ring compounds, of both the aromatic as well as cycloparaffin groups are sufficiently similar to the properties of "high-V.I." petroleum fractions to permit the conclusion that such lubricating oils are composed of mixtures of the type of hydrocarbons just mentioned. This cannot be said of the "low-V.I." fractions and solvent extracts. The data on Table 16 shows that the viscosity of such highly cyclic lubricating oils decreases substantially on hydrogenation. The hydrogenation was—as seen from the molecular weight—carried out so carefully that no cracking took place. All aromatic rings must therefore have been changed into the corresponding naphthene rings. On inspection of so far reported data, we find that conversion of benzene to cyclohexane derivatives and naphthalene to decaline derivatives is invariably followed by viscosity (and $\Delta H\ddagger$) increase. Hydrocarbons which behave like the "corresponding" petroleum fractions have yet to be synthesized. It could, of course, be argued that the high viscosity was caused by oxygen and sulfur compounds, inasmuch as it has been demonstrated that the high viscosity of many lubricating oils is to a large extent due to presence of "petroleum resins,"[38] which contain apparently quite a few oxygen and sulfur compounds (Table 17). It is also obvious that in the course of hydrogenation these compounds are reduced to hydrocarbons. On the other hand only hydroxyl and carboxy groups are known to increase η and $\Delta H\ddagger$ materially above the value of the corresponding hydrocarbons. Substitution with sulfur or oxygen in any other form does hardly influence η and $\Delta H\ddagger$ as seen on Table 18. Neither the acidity nor the acetyl-value of "petroleum resins" is as a rule high enough to justify the assumption that OH and COOH groups be the cause of their high viscosity and not the geometry of the molecule. We believe therefore that it is safe to say: The viscosity properties of highly cyclic petroleum fractions preclude comparison with any so far synthesized hydrocarbon.*

*Except, perhaps, alkylated anthracenes, hydrogenation products of which have not yet been examined.

TABLE 18

Comparison of the viscosity of non-hydrocarbons and hydrocarbons of similar molecular structure.

SUBSTANCE	M	Vis. @ 20° C. (Poise)	$\Delta H\pm$ cal/mole
n-undecane	156	.0117	2,600
di-n-amyl ether	156	.0108	2,650
n-amyl-n-butyrate	158	.0121	3,300
n-nonane-thiol-2	160	.0148	2,750
Pelargonic Acid	158	.0806	4,400
Octanol-2	130	.0800	7,000

III.3 The Viscosity-Pressure Function

The increase of the viscosity of lubricating oils with pressure has been the subject of a number of investigations during the past 15 years.[39] The purpose of all these investigations was to shed additional light on the behavior of lubricating oils in bearings. Such a study was, and still is, certainly necessary, since the specific pressures in journal bearings of internal combustion motors have been rising steadily in the past few years, and fall now, where 3000 psi is not at all unusual in airplane engines, well within the range of pressure effects on the viscosity. A few such data have been assembled on Table 19. Two relations are immediately obvious from inspection of these data: a. the proportionality between the pressure coefficient and the temperature coeffi-

TABLE 17

Effect of Petroleum Resins on Viscosity[38]

OIL	DATA OF OIL							DATA OF RESIN	
	d_4^{20}	μ 50° C. Stokes	Wp	Mol. Weight	Aniline Point °C.	Conradson Carbon %	Resin Percent	Mol. Weight	η 50° C. Poise
Penna. Brt. Stock	.898	2.44	1.88	800	122	1.50	13.3	1700	130
Same deresined	.884	1.65	1.83	680	127	.30	....	....	....
Russ Brt. Stock	.902	2.48	2.18	670	120	.85	10.1	400	14
Same deresined	.894	1.75	2.05	700	126	.27	....	....	....
Penna. Cyl. Stock	.902	4.56	1.85	1010	....	2.90	16.1	....	130
Same deresined	.879	1.77	1.63	740	....	.50	....	....	....
Mid-Cont. Cyl. Stock	.930	5.55	2.95	800	....	2.80	17.4	3600	....
Same deresined	.903	1.67	2.30	600	120.5	.33	....	....	....
Russ Distillate	.913	1.67	2.75	550	105	.45	10.1	300	28
Same deresined	.896	.91	2.38	580	110	.10	....	....	....
Same Acid Treated	.899	1.14	2.69	520	110	.10	4.2	....	10
and deresined	.893	.87	2.32	540	112	.04	....	....	....
Roumanian Distillate	.966	2.74	12.4	346	58	.15	11.8	480	13
Same deresined	.958	2.00	10.3	340	67	.05	....	....	....

TABLE 19
The Influence of Pressure on the Viscosity of Lubricating Oils and Related Substances

Oil	t °C.	Viscosity (Poise) at p=1 atm	Viscosity (Poise) at 600 atm	$\Delta V\ddagger$ cm³	W_{p0}	W_{p600}
Penna. Oil	38	.401	1.40		1.73	1.32
	99	.058	.178			
Same, Acetone-Raffinate	38	.358	1.33	51	1.61	1.34
	99	.057	.163	47		
Same Acetone-Extract	38	1.020	4.45	65	3.51	2.67
	99	.081	.21			
Calif. Lube Oil	54.4	.42	2.60	80		
	99	.08	.32			
Russian Lube Oil	38	.32	1.48	65		
	99	.04	.11	42		
Russian Bright Stock	38	5.12	26.1	65		
	99	.25	.82	61		
Roumanian Lube Oil No. 1	38	.21	.87			
	99	.04	.08			
Roumanian Lube Oil No. 2	38	4.53	50.1			
	99	.16	.59			
Castor Oil	39	2.50	6.80	40		
	100	.20	.33	24		
Linseed Oil	20	.476	.92	25		
	50	.179	.308	23		

cient of lubricating oils, which had already been observed by Kiesskalt,[39] and b. the increase in $\Delta H\ddagger$ but decrease of W_p (increase in V.I.) with pressure in the case of highly cyclic oils.

As the first approximation the relationship between pressure and viscosity can be represented by the empirical formula.

$$\log \frac{\eta p}{\eta} = \alpha_\tau \cdot P \qquad (7)$$

which has been given by Kiesskalt[39] and Everett.[40] On closer examination it will be found that α_τ is not constant, but increases slowly with pressure. For the purpose of the automotive engineer, that is, up to 500 atmospheres pressure, equation 7 can be considered valid.

The theoretical interpretation of the pressure-viscosity function is quite simple (following Eyring's theory),[41] since according to elementary thermodynamics

$$\left(\frac{\delta \Delta F\ddagger}{\delta p}\right)_\tau = \Delta V\ddagger \qquad (8)$$

meaning that the change of free energy of activation with pressure is equal to the change of volume (per molecule) $\Delta V\ddagger$ with activation. Or in other words, the change of viscosity with pressure is a measure of the size of the hole required by the activated molecule to move into. Remembering the defining equation of $\Delta F\ddagger$ (5) we see that the theoretically founded formula (8) also connects log η with the pressure just as (7), only that now the pressure coefficient has a readily understandable meaning. From other considerations, we also know[42] that long-chain molecules move along a segment at a time, requiring therefore a smaller hole for each movement than the more spherical molecules which can move only all at once or not at all. This explains why the pressure coefficient of viscosity $\Delta V\ddagger$ is larger for cyclic compounds than for long chain (paraffinic) ones.* The reason for the increase in V.I. with pressure in the case of low V.I. (cyclic)oils is their comparatively high viscosity-pressure coefficient over the entire temperature range, which appears reasonable in the light of the interpretation of $\Delta V\ddagger$ given above.

* A quantitative relationship between $\Delta V\ddagger$ and $\Delta H\ddagger$ has been found by the author which will be published shortly.

At higher pressures (above 1000 atmospheres) the viscosity-pressure coefficient $\Delta V\ddagger$ often starts to increase quite rapidly. When compressed to an extent that only a small fraction of the "free volume" is left pure compounds will suddenly solidify with volume contraction and all signs of a true melting point.[12] Fixed oils (animal and vegetable oils) start to crystallize partially at 700 to 900 atmospheres and behave like colloidal systems (in that the viscosity becomes a function of shear rate and the length of time that the pressure had been applied) up till 2500 to 3500 atmospheres when they will solidify completely.[16,17] Among petroleum oils only the more paraffinic lubricating oils will show such partial crystallization and solidification phenomena under high pressure. Other lubricating oil will simply and steadily increase in viscosity. It is remarkable that those oils which solidify remain solid (or pastes) for a short while even after the pressure has been completely released.

III.4 The Viscosity of Mixtures

The viscosity of a mixture of two liquids is usually dominated by the influence of the low viscosity component. This observation has been given expression in mathematical form in the two empirical equations.

$$\log \eta_{12} = n_1 \log \eta_1 + n_2 \log \eta_2 \qquad (9)$$

$$\frac{1}{\eta_{12}} = \phi_1/\eta_1 + \phi_2/\eta_2 \qquad (10)$$

where $n_{1,2}$ = molfractions $\phi_{1,2}$ = volumfractions

Equation (9) is due to Arrhenius[43] and equation (10) has been strongly advocated by Bingham.[44] The latter equation gives very poor results for lubricating oils (and other substances of high viscosity) predicting very much lower viscosities than are observed experimentally. Arrhenius' equation, however, fits a large number of experimental results quite well[45] and can well be derived from Eyring's theory of viscosity. This is of interest insofar as it permits us to explain—and eventually predict—differences between calculated and observed mixture-viscosities. But, before entering into a discussion of the theoretical aspects of the mixture law, it may be useful to record a few experimental findings:

1. Oils which do not differ very much in average molecular weight and general character (such as $\Delta H\ddagger$, W_p, V.I.) follow equation (9) quite closely, as shown on Table 20 as expressed by constancy of factor "Z."

2. In case the two components differ widely in

TABLE 20
The Viscosity of Lube Oil Blends

	Oil 1	Oil 2	μ 20° C. Stokes	μ 50° C. Stokes	μ 80° C. Stokes	Z@50° C.	W_p
A	100 percent	0%	19.00	2.50	.62	....	1.88
	80	20	7.01	1.14	.33	1.27	1.81
	50	50	1.96	.41	.14	1.25	1.82
	20	80	.61	.17	.069	1.25	1.78
	0	100	.31	.096	.044	....	1.88
B	100	0	116.00	2.93	.38	....	6.0
	50	50	1.68	.29	.090	2.02	3.40
	20	80	.52	.14	.069	2.01	2.15
	0	100	.31	.096	.044	....	1.88
B	50	50	3.62	.484	.135	1.83	3.72
	20	80	1.31	.26	.087	1.81	2.85
	0	100	.78	.19	.072	....	2.31
A	80	20 Bens.	.70	.21	.089	2.83	1.30
	50	50 Bens.	.061	.....	.....	2.72	....
B	80	20 Bens.	.37	.10	.043	5.16	2.60
	100 Blown Rapeseed		19.00	3.36	.95		1.38
	80	20 Bens.	1.99	.95	.54	1.55	1.20

Oil 1-A: Penna-Brightstock.
Oil 1-B: Extremely aromatic lube fraction (V.I. much below 0).
Oil 2: White Oils, except where noted as Benzene.

general character the following rules hold: The oil of low $\Delta H\ddagger/M$, W_p (high V.I.) always dominates the mixture; if the high V.I. oil has the lower viscosity, the mixture will have a lower viscosity than equation (9) predicts; if the high V.I. oil has the higher viscosity, the mixture will have a higher viscosity than equation (9) predicts. The latter rule is especially obvious when determining the effect of fuel dilution on the viscosity of lubricating oils.[46]

3. The temperature coefficient of the viscosity of blends is very difficult to predict. W_p is arithmetically additive within the range $W_p = 1.8$ to 4.0, provided the components are not too dissimilar in character.[47,48] W_p is not additive for mixtures of non-hydrocarbons with lubricating oils (Table 21), or fractions of widely different molecular weight. The latter case is of considerable practical interest, since it has been observed that the viscosity-temperature curve of a blend becomes that much "flatter" the larger the molecular weight difference between the components. This rule is quite general. When vacuum distilling lubricating oils, cuts of narrow boiling range will be found lower in V.I. (higher in W_p) than those of wide boiling range (Table 22). Most impressive is, however, the application of this rule to mixtures of lubricating oils and high polymers, such as polyisobutylenes and polymers of methacrylic acid esters and derived co-polymers (Table 23). The usefulness of these blends is as yet limited to comparatively low temperature service, since the concentration of high-polymers required to give the desired m or W_p value (V.I. is meaningless here) is high enough to increase the viscosity to impractical levels unless a thin oil (of relatively high volatility) is used as base stock. It is noteworthy that the polyisobutylenes increase the viscosity much more than acrylic polymers of similar molecular weight ranges, the latter may, therefore, have some future application in the field of automotive lubricants. At present, these blends are mostly used as power-transmission fluids in servo mechanisms, where temperature independence of viscosity is of vital importance.

TABLE 21

The Limitation of Additivity Rules for Wp

Percent Oil No. 1	Percent Oil No. 2	Wp_1/Wp_2	Wp Observed	Wp Calculated	Difference
50	50	2.23	2.70	2.94	—.24
50	50	1.82	2.90	3.15	—.25
50	50	1.68	3.10	3.30	—.20
30	70	1.30	1.74	1.67	+.07

TABLE 22

Influence of Fractionation on Viscosity—Index

	Vis. @ 100° F. (Stokes)	V.I.
I Original Lube Fraction*	.328	114
II 10th (middle) fraction obtained from distillation of I*	.328	101
III Original Lube Fraction	.52	50
IV 6th (middle) fraction obtained from distillation of III	.53	32

* From F. D. Rossini, A.P.I.-Proc. 16 III, 63 (1935).

TABLE 23

Viscosity of Polymer Solutions in Lubricating Oil

	Percent (Weight)	Viscosity at 100° F. CST	Δ log cst/ Δ %	V.-I.	Δ cst/ Δ V.-I.
Oil	100	44	..	69	..
+ Poly-isobutylene*	0.5	54	.176	93	.42
+ Poly-isobutylene*	1.0	65	.166	102	1.22
+ Poly-isobutylene*	2.0	95	.166	115	2.30
+ Poly-isobutylene*	3.0	138	.162	124	4.80
+Poly-acrylicesters†	.25	48	.148	85	.24
+Poly-acrylicesters†	.50	51.5	.124	96	.35
+Poly-acrylicesters†	1.0	60	.132	109	.65
+Poly-acrylicesters†	3.0	112	.135	130	2.48

* $\overline{M}$~20,000. † $\overline{M}$~15,000.

TABLE 24

Abscissae Ruling for the Lederer Blending Viscosity-Diagram for Various Values of "Z" Out of Equation[18]

x= 0.9	1.0	1.1	1.2	1.3	1.4
11.0	10	9.0	9.47	7.9	7.4
21.7	20	16.6	17.2	16.1	15.2
32.2	30	28.0	26.3	24.8	23.4
42.6	40	37.8	35.7	33.9	32.2
52.6	50	47.6	45.5	43.5	41.7
62.5	60	57.7	55.6	53.6	51.7
72.2	70	68.0	66.0	64.2	62.5
81.1	80	78.4	76.9	75.5	74.0
90.9	90	89.1	88.2	87.4	86.5
100.0	100.0	100.0	100.0	100.0	100.0

Eyring's theory of viscosity gives for the mixture law:

$$\Delta F\ddagger_{12} = n_1 \Delta F\ddagger_1 + n_2 \Delta F\ddagger_2 - \Delta F_m/2.45 \qquad (11)$$

where ΔF_m = excess free energy of mixing. Equation (11) is based on the assumption that the probability to move is equal for the molecules of each component of the mixture (or on random-flow[49]), influenced only by the excess free energy of mixing. For "ideal" mixtures ΔF_m is zero and (11) becomes practically equal to Arrhenius' equation (9). Lederer[50] was the first to observe that deviation from equation (9) may not only be due to heat of mixing (which is very small for most hydrocarbon systems) but also to immobilization of the molecules of one component in the neighborhood of the molecules of the other, leading to a mixture law of the form

$$\log \eta_{12} = \frac{P_1/M_1}{P_1/M_1 + P_2/SM_2} \log \eta_1 + \frac{P_2/SM_2}{P_1/M + P_2/SM_2} \log \eta_2 \qquad (12)$$

where: S = degree of solvation of species 2 with respect to species 1.

Equation (12) can be given the simple form also due to Lederer[50]

$$\frac{P_1}{P_1 + ZP_2} = \frac{\log \eta - \log \eta_2}{\log \eta_1 - \log \eta_2} \qquad (13)$$

where $Z = \frac{M_1}{M_2} \cdot \frac{1}{S}$ / $P_{1,2}$ = wt. percent.

Using the left hand side of equation (13) as abscissa and log η as ordinate a series of graphs for different values of Z, can be constructed which permit the prediction of mixture viscosities with a high degree of accuracy, after one blend (preferably 1:1 weight ratio) has been made to determine the value of Z to be used. The abscissa values for commonly occurring Z's have been calculated and assembled on Table 24. This method of correction of equation (9) breaks down whenever the heat of mixing cannot be neglected. But, this rarely happens in the field of lubricants as is brought out by the constancy of Z (or S) for most blends so far investigated, typical examples as shown on Tables 20 and 25. Some of the newer heavy-duty motor-oil additives have been observed to deviate from the additivity law (13) sufficiently to indicate fairly high values for an interaction energy ΔHm.

For a while it had been believed the temperature coefficient of viscosity follows a mixture law of the form

$$\Delta H\ddagger_{12} = n_1 \Delta H\ddagger_1 + n_2 \Delta H\ddagger_2 - \Delta H_m \qquad (14)$$

where ΔH_m is the integral heat of mixing.[51]

This simple relationship could not be confirmed experimentally, and it is from the present point of view (Eyring's) hardly to be expected that such a relation should hold; since—especially in the case

of higher molecular weight hydrocarbon mixtures—changes in the entropy of activation ($\Delta S\ddagger$) and its temperature coefficient upon mixing are the primary cause of deviations from "ideality" and readily calculated from first principles. The discussion of this question is, however, beyond the scope of this paper. In closing of this section it should, however, be remarked, that the peculiar behavior of high-polymer blends with lubricating oil is almost solely due to the dominating position of $\Delta S\ddagger$ in the viscosity formula of high polymers. The viscosity-temperature curves of high-polymers suggest[42] that all segments of a large molecule have to cooperate in a certain way to accomplish its forward motion, resulting in a large *decrease* of entropy in the process. $\Delta S\ddagger$ can accordingly be directly related to the chain length Z by an equation of the form

$$\Delta S\ddagger = A(Z)^{4/3} + B$$

where $B \sim 7$ and $A \sim -.5$, while $\Delta H\ddagger$ is almost independent of the molecular weight of high-polymer and varies for different types between 8 and 11 kcal/mole. Even if equation (11) should only be a first order approximation, comparison of $\Delta S\ddagger$ and $\Delta H\ddagger$ values of lubricating oils and polymers must of necessity lead to the prediction (which experiment has proven correct) that W_p (or the V.I.) will be improved by addition of linear high polymers in proportion to the square root of their chain length. The upper limit of the molecular weight of lubricating-oil additives is given by the tendency to gell and mechanical fragility which increase exponentially with chain length. The decrease in mechanical stability especially will be discussed in a subsequent paragraph.

The viscosity-pressure curves of lubricating oil blends have so far not been reported in the literature. It is to be expected that the pressure coefficient $\Delta V\ddagger$ follows a mixture law of the form

$$\Delta V\ddagger_{12} = n_1 \Delta V\ddagger_1 + n_2 \Delta V\ddagger_2 - \Delta V_m \qquad (15)$$

where ΔV_m = molar volume increase on mixing.

The latter is usually close to zero for blends of lubricating oils.

As much as a completely satisfactory theory and general correlation of viscosity data is still wanting, we can from this vantage point clearly discern certain regularities: The preferentially linear (paraffinic) constituted hydrocarbon oils (and also non-hydrocarbons!) are *slow* to change their viscosity with temperature, with pressure, and with dilution (mixing). The more cyclic (spherically) constituted hydrocarbons in contrast change their viscosity rapidly with temperature, pressure, and dilution (mixing). The variation of these three variables, temperature, pressure and concentration has one effect in common, that is, the variation of the distance between the molecules of the liquid under consideration. A single parameter should therefore characterize the viscosity behavior of a liquid with respect to all three variables of state. This is indeed possible. The author has recently shown* that a significant portion of the energy of activation of viscosity $\Delta H\ddagger$ is expressive of the rate of change of potential energy between molecules with change of their mutual distance. This portion $\Delta H\ddagger^b$ is small for linear molecules and large for cyclic (spherical) ones, see Table 26.

This parameter $\Delta H\ddagger^b$ is a function of $\Delta V\ddagger$, the pressure coefficient of viscosity, the magnitude of which depends essentially upon the flexibility of the molecule. As long-chain paraffinic molecules have been found to move only in small segments, while the rigid cyclic compounds can move only as a whole, or in large segments, one can see that a change of environment—as brought about by dilution or mixing—will effect the viscosity of cyclic compounds very much more than the viscosity of paraffinic (long chain) compounds. The relationship between chemical structure of lubricants and the temperature, pressure and dilution susceptibility of their viscosity is thereby brought on a common denominator: the flexibility of their molecules: The more flexible the molecules, the smaller are all three susceptibility coefficients, and the more rigid the larger are these coefficients.

*A. Bondi, ACS—Petroleum Division, Meeting in print 1945.

TABLE 25.

The Degree of Solvatation S in Various Systems Involving Lubricating Oils

SOLVENT	SOLUTE	Mol. Wt.	η 20° C. Poise	S_{20}
Benzene	White Oil	290	.26	1.33
Benzene	White Oil	374	.68	1.51
Benzene	White Oil	448	2.03	1.70
Benzene	Penn. Neutral	350	.67	1.60
Benzene	Coastal Dist	350	112.0	.86
Benzene	Penn. Br. St.	790	19.0	3.73
Benzene	Olive Oil	870	.81	7.73
Benzene	Castor Oil	940	9.74	6.40

TABLE 26

Heat of Activation for Hole Formation $\Delta H^b\ddagger$ (Indicating the Change of Potential Energy Between Two Molecules Accompanying Their Motion Past Each Other)

Substance	M	$\Delta H\ddagger^b$
N-Octane	114	.98
Toluene	92	1.35
Paraffinic Lube	395	4.50
Aromatic Lube	405	8.40

III.5 Anomalous Flow of Lubricating Oils

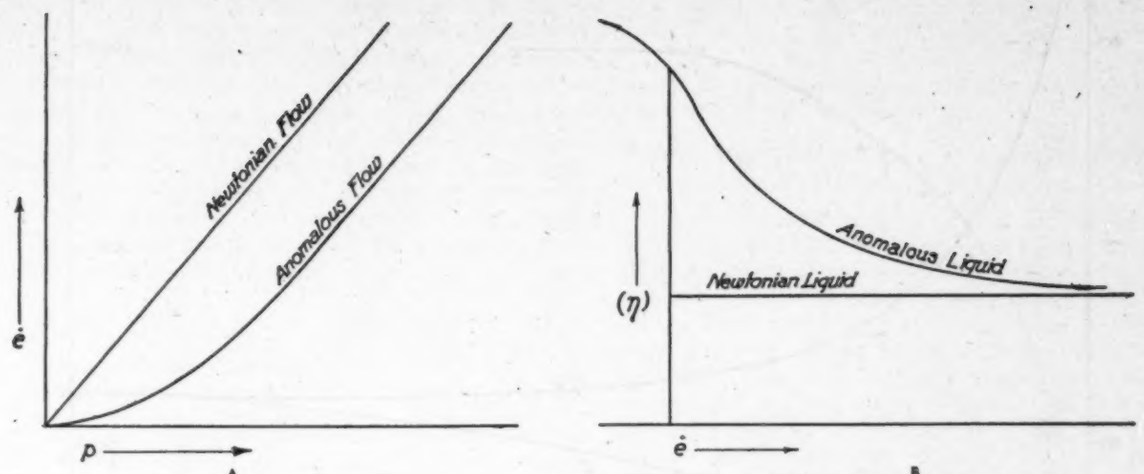
According to the fundamental equations (1) and (2) cited in the beginning of this article the rate of flow through a capillary tube should at all times be directly proportional to the differential pressure between the two ends of the tube, or in more general terms the rate of deformation of a liquid should be proportional to applied shear stress. These laws apply to all ordinary liquids (and also to lubricating oils) at flow-velocities not leading to "turbulence," a condition which usually prevails when

$$\mathrm{Re} = \frac{u \cdot D}{\mu} < 2000,$$

where u = velocity of flow, D = diameter of tube, μ = kinematic viscosity of liquid.

The high viscosity of most lubricating oils will obviously preclude encountering of turbulent flow in problems involving reasonable energy consumption.

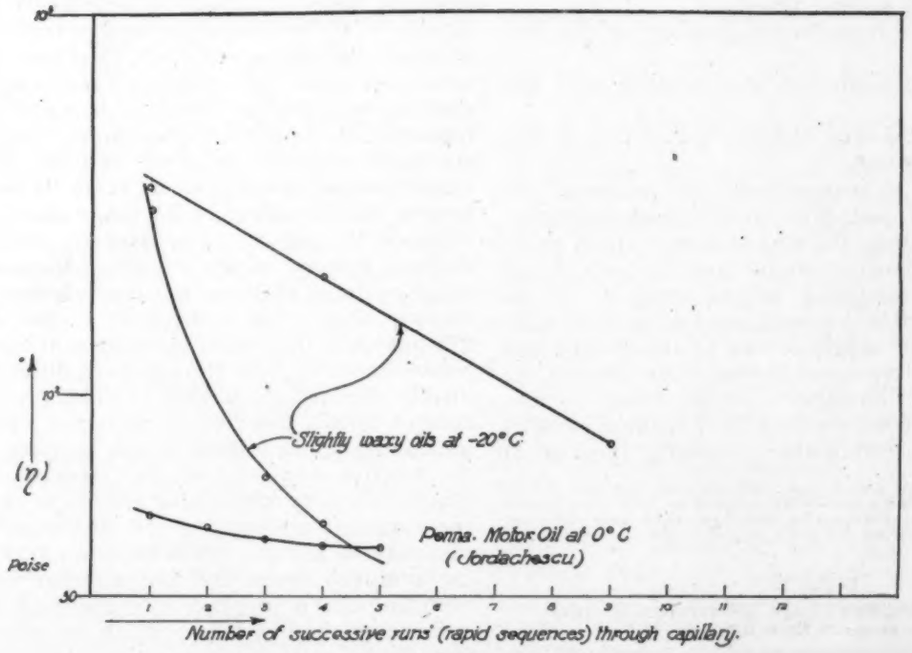
Under most ordinary conditions lubricating oils do behave in accordance with equations (1) and (2). Sometimes, however, marked deviations from the prescribed relationship between p and é can be observed. Such anomalies of lubricating oils always appear as more than proportional increase of flow rate with pressure differential (or shear stress). This gives the impression of an apparent decrease of vis-



A
Strain rate (rate of shear) vs. shear stress.

B
Apparent viscosity vs. rate of shear.

FIGURE 13
Typical anomalous flow of lubricating oils.



Change of apparent viscosity (η) of lubricating oils at low temperature by working

FIGURE 14

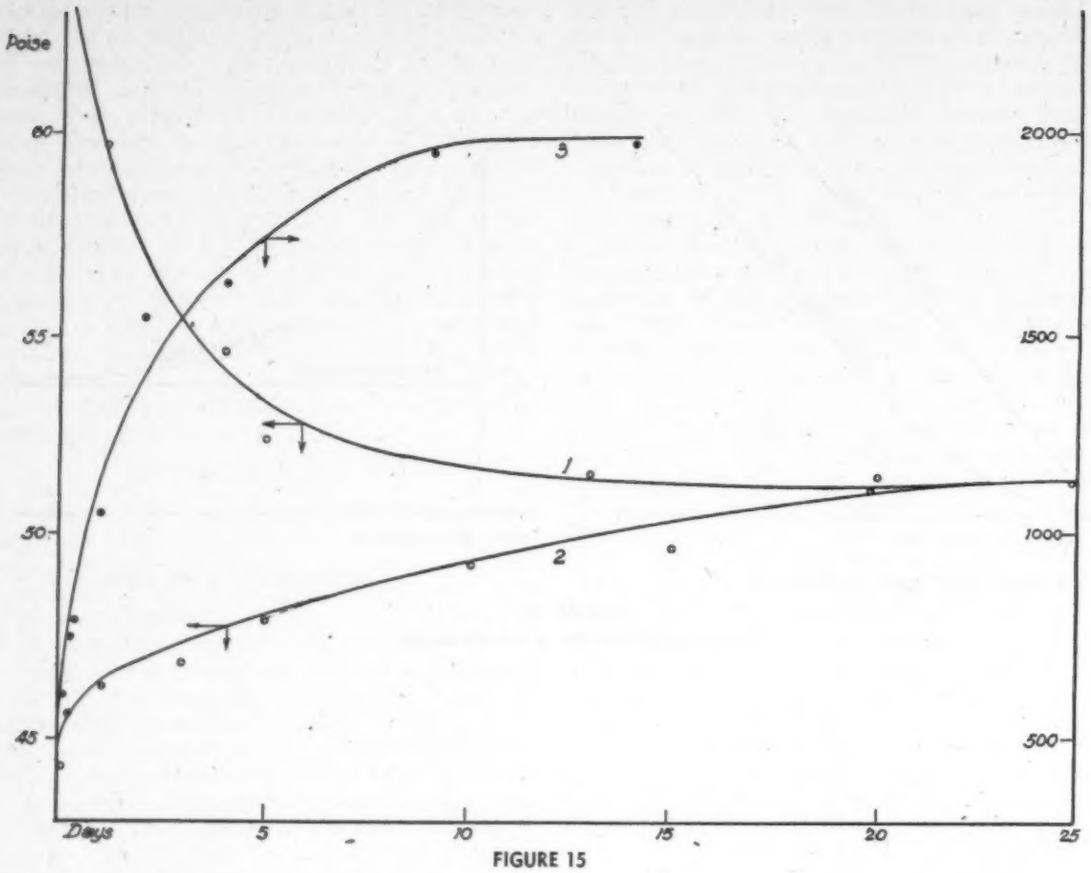


FIGURE 15

cosity with increasing shear stress (Figure 13). As causes of such behavior are now recognized:

a. Presence of a second phase;

b. Existence of a temperature gradient within the flowing liquid;

c. Orientation of molecules axis parallel with the directions of flow.

d. Irreversible changes of components due to the action of shear stresses.

Case a. Several investigations[52,53,54] showed, by electrical, thermal and dilatometric measurements, that those lubricating oils, which show a cloud point (not due to moisture), contain often a fairly large percentage of crystallizing hydrocarbons (5 to 20 percent). The fractional crystallization of these substances starts in the neighborhood of the cloud-point temperature and often extends over more than 30° C. below this point. Comparison of the effect on viscosity with paraffin waxes showed that these crystallizing hydrocarbons often differ markedly in physical properties from ordinary waxes.[53] The effect of such partial crystallization on the viscosity of lubricating oils has been reported on repeatedly in the past decade.[53,55,56,57,58,59] The following viscosity anomalies indicate the appearance of this new phase: The measured viscosity is higher than predicted on the viscosity-temperature chart, it becomes smaller with repeated viscosity determinations, when such runs are made in short sequence and increases if but a single determination is made every 24 hours on an oil kept at low temperature for many days, as shown on Figures 14 and 15; the viscosity depends on the thermal history of the sample, assuming enormous value on rapid chilling, but much lower values when cooling slowly (at rate of 5° C. per hour) Table 27; but most important is the non-linear relationship between rate of flow and pressure differential, clearly visible on Figures 16 and 17. The rapid increase in rate of flow (decrease of apparent viscosity) with increasing applied shear stress is quite indicative of the relative weakness of the "structure" of the new phase.* At very high shear stress (or rates of shear) the apparent viscosity of the system approaches the viscosity of the oil, but sometimes stays sufficiently far removed from the extrapolated viscosity temperature curve to make the standard procedure of estimating the low-temperature viscosity of lubricating oils by extra polation of the usual viscosity line[60] of questionable accuracy even for engineering purposes. If we consider that in a *starting* automotive engine the rates of shear range from $\sim 5\ sec^{-1}$ in the oil pump lines to $2000\ sec^{-1}$ in the main bearings, we shall realize that the viscosity behavior outlined above and on Table 28 is of more than academic interest. The effect of pour-point depressants and

*It has been mentioned above that high pressure produces effects similar to low temperature on "wax" containing oils, i.e., partial crystallizable substances. Figure 17 brings out the qualitative similarity of the low temperature and high pressure flow anomalies.

TABLE 27

The Effect of Cooling Rate on Low Temperature Viscosity (Shear Stress = 1200 Dyne/Cm²)

	VISCOSITY AT—20° C.	
	Cooled Slowly*	Chilled Rapidly
1. 500 Pale Oil	650	11,000 Poise
2. 300 White Oil + .5 percent ozokerite	3500	10,500 Poise
3. No. 2 + .5 percent Paraflow	227	3,700 Poise
4. 300 White Oil + .5 percent paraffin wax	1340	6,500 Poise

* Rate:— 5° C./hour.

diluents on the phenomena of low-temperature viscosity is quite astounding, and emphasizes the soundness of the now generally adopted winter safeguard of lubricant dilution. The more recent movement to supply at least heavy-duty engines with built-in crankcase heating equipment is, however, very much safer from the point of view of proper lubrication.

Case b. The temperature gradient in flowing oil due to conversion of the frictional work into heat has only recently been realized as one of the possible causes of apparently decreasing viscosity with increasing shear stress (or velocity gradients).[61,62,63] The relation between the amount of heat produced and the rate of shear is:

$$H^1 = \frac{\eta \cdot \dot{e}^2}{J} = \frac{\bar{p} \cdot \dot{e}}{J} \text{ [cal/cm}^3\text{]} \qquad (16)$$

where J = mechanical heat equivalent, and $\dot{e}$ = rate of shear, $\bar{p}$ = shear stress.

Numerical calculations will indicate that a sensible amount of heat will be produced only at quite high shear stresses and flow rates (where $\bar{p} \cdot \dot{e} \geqslant 10^7$). The mathematical treatment of the energy balance around the flowing liquid leads to rather complicated expressions. The heat conductivity of oils is, however, so small, that to a good approximation the *rapid* oil flow through a capillary can be treated as adiabatic[62,63] leading to the simple relation between the measured viscosity and the actual viscosity:

$$\eta/\eta_o = \exp(-\Delta P\beta/cJ) \qquad (17)$$

where ΔP = pressure differential, c = specific heat of the oil, and β = viscosity temperature coefficient for Reynolds' equation $\eta_\theta = \eta_o e^{-\beta\theta}$, for a small temperature interval η.

Data on Table 29 brings out the range of applicability of this equation. These data also demonstrate that the temperature gradient correction cannot very well be neglected in high-flow-rate viscosimetry. The heat effect is much more serious in concentric cylinder viscosimeters, where the heat produced is not carried away by the oil but has to be conducted away, leading to rather high temperature gradients even at fairly low shear stresses. According to Hagg[64] the ratio of measured to actual viscosity in such instruments can be expressed by the formula

$$\eta/\eta_o = \frac{1}{1 + \frac{\eta_o\beta}{K \cdot J} u^2} \qquad (18)$$

where K = heat conductivity and u = circumferential velocity of moving cylinder.

The technical significance of equation (18) will be discussed in the chapter on lubrication.

Case c. The orientation of molecules, axis parallel with the direction of flow, had been suspected by Kyropoulos[65] and others[66,67] as the cause of the observed decrease of viscosity (and di-electric constant) at high rates of shear. These measurements had been performed at shear rates of up to 50,000 sec^{-1} and shear stresses up to 100,000 dyn/cm². Later observations have been carried out at shear rates of up to 1,000,000 sec^{-1} and shear stresses up to 200,000 dyn/cm².[68,69] In nearly all cases the observed viscosity decrease is of the same order of magnitude as the calculated temperature effect, except Neale's data, which are, however, open to considerable criticism. With the exception of such lubricating oils which were known to contain some higher-molecular-weight constituents, all ordinary lubricating oils may not show any flow orientation phenomena. Only recently has this problem been attacked from the theoretical side[70] where it has been shown that even for straight-chain hydrocarbons of the molecular weight (500) of medium heavy lubricating oils a shear stress in excess of 200,000 dyn/cm² is required to produce noticeable viscosity reduction due to flow orientation. Since the length/diameter ratio, which determines the ease of flow orientation, is smaller for the molecules of lubricating oils than for the assumed straight-chain hydrocarbon flow orientation should not become important in ordinary lubricating oils at shear stresses less than 500,000 dyn/cm². Lubricants, the viscosity of which depends much on added higher-molecular-weight materials, such as "voltolized" oils, Paratone or Acryloid, however, should show considerable decrease in viscosity at high shear stresses due to orientation, as the latter depends on the square of the chain length. The correctness of this consequence of the theory is indicated by the results of Frossel[69] and Branard.[58] Theoretical considerations[70] also lead to the conclusion that flow orientation cannot be well observed in capillary instruments due to the long relaxation time in viscous media.

Case d. Closely connected with the phenomena of flow orientation is the irreversible viscosity decrease of certain lubricating-oil blends after having been exposed to high shear stresses. Very soon after the introduction of the use of high polymers as "viscosity-index-improvers" it was observed that sometimes the viscosity of these blends did not only decrease during high-flow-rate viscosity measurements (due to flow orientation), but had also permanently decreased to a more or less serious extent. Several investigators recognized[74,75] that high polymers can be degraded by mechanical means, especially high shear stresses, the easier the longer the molecule. Specifications have therefore been set up which require such blends to pass repeatedly through narrow orifices at high differential pressures without subsequent permanent loss in viscosity in order to screen out too "fragile" high polymers as V.-I. im-

TABLE 28

Effect of Dewaxing, Paraflow and Dilution on Viscosity

OIL	Viscosity (Poise) at 100° C.	Viscosity (Poise) at −15° C.	Pour Point °C.
Penna. 8	.10	1820	−5
Same solvent refined	.09	3330	−4
Same 0.5 percent Paraflow	.09	103	−12
Same Dewaxed	.10	665	−8
Same Diluted with 10 percent kerosene	.07	39	....

TABLE 29

The Magnitude of the Temperature Increase and Corresponding Viscosity Decrease in Rapidly Flowing Oils Due to Inner Friction (from the Work of Hersey and Zimmer[62])

Exper. Nr.	Oil Viscosity at Operating Temp. Poise	Rate of Shear 10^6 Sec.$^{-1}$	Pressure Drop Psi	Temp. Increase of Oil °F.	η/η_0 Observed	η/η_0 Calc. from eq. (17)
A 1	1.35	1.5	4450	26.4	.14	.37
B 2	1.34	1.1	4430	33.2	.33	.39
C 3	3.78	.104	1110	10.0	.61	.76
C 4	2.70	.022	127	1.2	.86	.94
C 5	.17	.010	112	.5	.93	.97

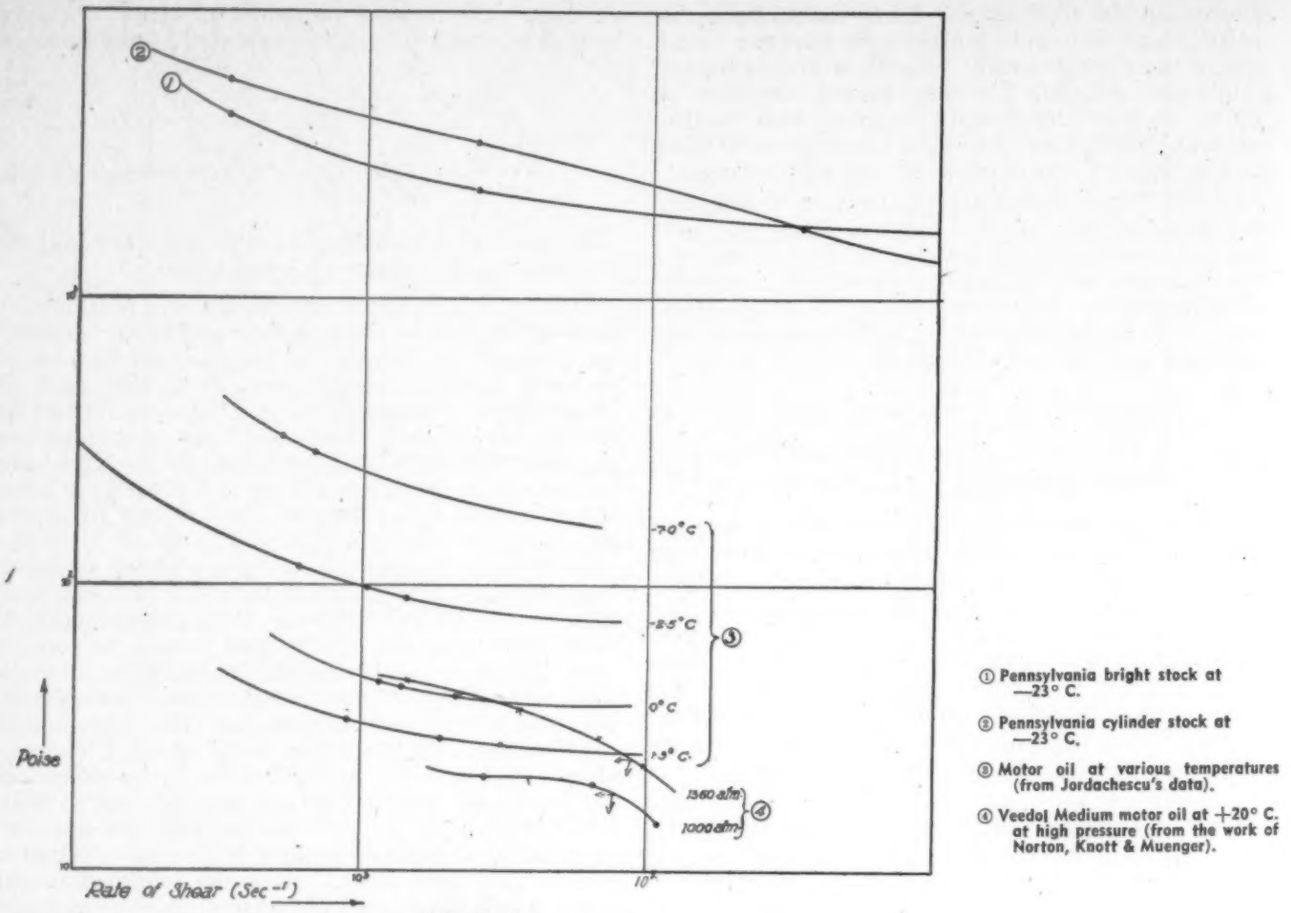

Poise
Rate of Shear (Sec⁻¹)
-70° C
-55° C
0° C
+5° C
1360 atm
1000 atm
① Pennsylvania bright stock at —23° C.
② Pennsylvania cylinder stock at —23° C.
③ Motor oil at various temperatures (from Jordachescu's data).
④ Veedol Medium motor oil at +20° C. at high pressure (from the work of Norton, Knott & Muenger).

FIGURE 16

Anomalous flow of lubricating oils: Viscosity vs. rate of shear diagram.

provers. But, only recently has an attempt been made to develop a theory which would predict such "fragility" as a function of molecule dimensions: Frenkel[76] has based this theory on the reasonable assumption that the same forces which orientate the molecule axis parallel with the direction of flow also tend to stretch this molecule. At a certain critical shear stress the molecule will be stretched beyond the strength of its weakest bond (in case of all equal bonds, the center bond) and split in two halves. The shear stress at which this happens is

$$\overline{p_o} = \frac{2F_o}{6\pi N^2 \alpha l} \qquad (19)$$

where: F_o = strength of bond, N = number of chain segments of radius α and length l.

Equation (19) predicts that the highest-molecular-weight polyisobutylene e. g., to survive a shear stress of 10^4 dyn/cm² is about 9000. This is somewhat lower than would have been expected, especially in view of the fact that commercial polymers always consist of mixtures containing components of higher and lower molecular weight than their nominal average molecular weight. Since—as we have just seen—the mechanical stability of a high polymer decreases sharply with increasing chain length, commercial products with the narrowest molecular-weight range among competitive products of equal average molecular weight, will show the smallest permanent reduction in viscosity after exposure to high shear stresses.

*See e.g. the work of the Special Research Committee on Lubrication of the A.S.M.E. Trans. A.S.M.E. 63, 631 (1941).

III.5 Lubrication

Much of the work which has been reviewed in this paper had been undertaken for the specific purpose of advancing the science of lubrication.* The large amount of data on the temperature and pressure functions of the viscosity of lubricating oils which grew out of this research has had as natural consequence the revision of the theory of lubrication to include proper expressions for the variation of viscosity with these variables of state.[77]

The old theories of lubrication considered the load-carrying capacity of a bearing as function of various dimensional factors and proportional to the product $\eta_t \cdot u$, where u = circumferential velocity of the shaft, and η_t = viscosity of lubricating oil at temperature of operation. At low speeds, low bearing pressures and "conservative" clearances between shaft and journal these "classical" theories of lubrication were fully sufficient for engineering calculations. The introduction of high speeds, small clearances, and high specific pressures required reconsideration of the premises on which the old design formulae had been based and led to the following results: At high velocities and small clearances so large an amount of heat is developed in the oil film that the heat conductivity of the lubricant determines the rate of heat loss from the film and not the rate of heat transfer from the bearing to the surrounding as assumed by classical bearing theory.[78] Consequently the assumption of a uniform temperature across the film of lubricating oil had to be abandoned, and be replaced by the concept of a tempera-

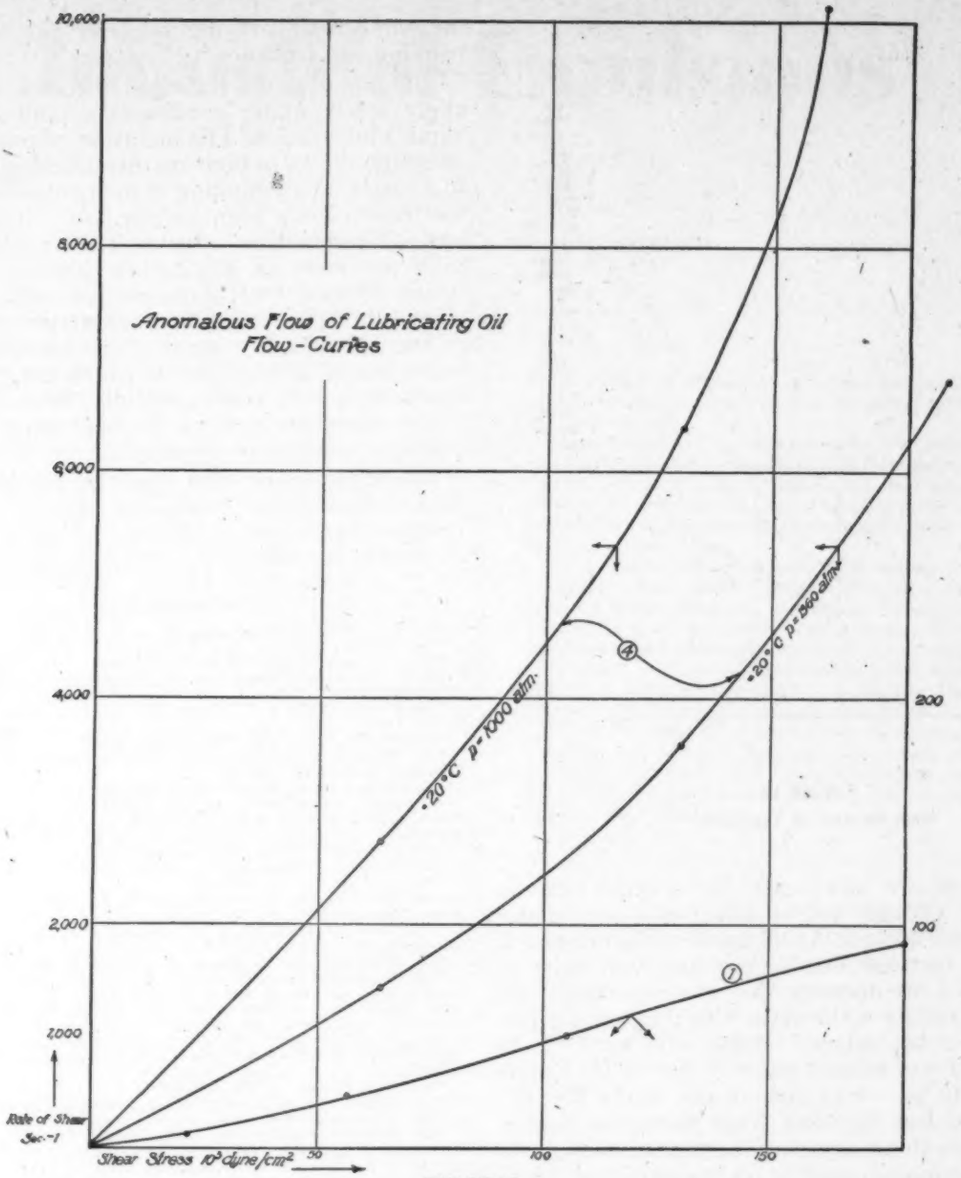


FIGURE 17

ture gradient within the film.[79,80,81,82,83] The fact that the rise in temperature is a function of the viscosity which is itself a function of temperature make a rigorous mathematical solution of the problem somewhat difficult and a completely satisfactory formulation has yet to be presented. A fair approximation is given by Hag[83] who obtains for the temperature rise at any point within the oil film

$$\Delta t = \frac{1}{\beta} \ln \left(1 + \frac{\eta_o \beta}{2KJ} u^2 \right) \qquad (20)$$

where β = expotential viscosity-temperature coefficient (as above), η_o = the nominal viscosity at the temperature of the journal u = circumferential velocity of the oil film at point under consideration.

For the ratio of actual to nominal viscosity at the point of highest temperature Hagg obtains the already mentioned relation:

$$\eta/\eta_o = \frac{1}{1 + \frac{\eta_o \beta}{2KJ} u^2} \qquad (18)$$

Remembering that the load-carrying capacity of an oil film is proportional to its viscosity, we see from equation (18) that the load-carrying capacity of an oil film is higher for high V.I. oils than for lower V.I. oils. A numerical example: at u = 12 cm/sec, η_o = 1 poise, K = .0004 cal. sec^{-1} cm^{-3} $°C^{-1}$, 100 V.I. oil gives η/η_o = .28 and a 0 V.I. oil η/η_o = .20, or in other words, the load carrying capacity of the 100 V.I. oil is about 30 percent higher than of the V.I. oil. On the basis of somewhat different reasoning Vogelpohl[81] concludes that the load-carrying capacity of a lubricant film (assuming equal η_o values) increases with decrease of the parameter $\frac{\beta}{Kc}$, where c = specific heat. It is interesting to observe that for the range of commercial petroleum-derived lubricating oils the value of this parameter varies only between 1.3 and 1.5×10^{-4}, for fatty oils (glycerides) between .8 and 1.1×10^{-4}, while the smallest observed value is that of sugar solution. A large fraction of lubricating effects, which had been ascribed to "oiliness" can therefore be predicted from hydrodynamic theory (see Vogelpohl's data on Figure 18). His theory *does not* cover the well known "E. P." effects of small percentages of active additives, which hardly change the parameter β/Kc. These relationships between load-carrying capacity and viscosity-tempera-

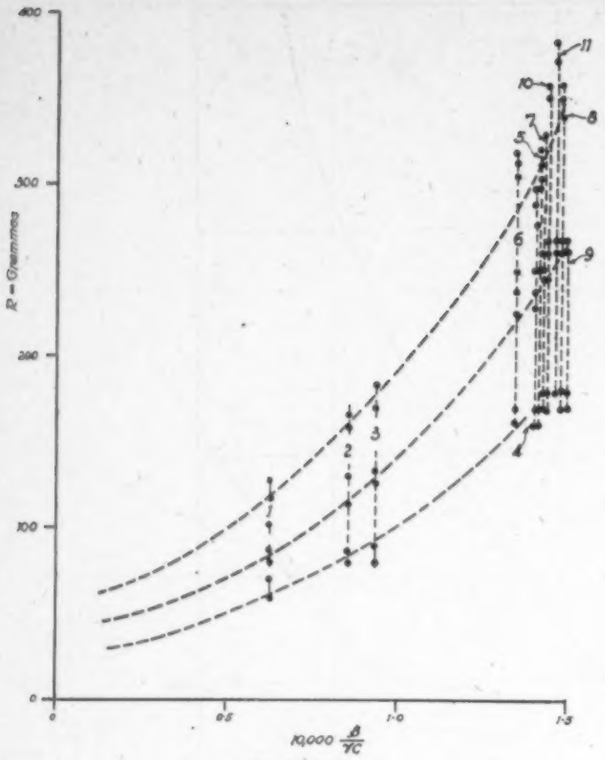


FIGURE 18
from the work of Vogelspohl[82]

ture coefficient are valid only for specific bearing pressure, low enough not to affect viscosity materially, i.e., below 500 psi. At higher bearing pressures, the viscosity increase due to pressure will start to compensate for the decrease due to temperature. To a good approximation the term η in the bearing formulae can thus be replaced by the term $\eta_o e^{\alpha_v p - \beta \Delta t}$, or since α_v and β are related by $\alpha_v \sim 3 \times 10^{-2}\beta$, $\eta/\eta_o = c \times p[\beta(4 \times 10^{-2}p - \Delta t)]$ (where the factor 3×10^{-2} has the dimension $Kg^{-1}cm^2$. This numerical factor, which indicates that a pressure increase of 35 Kg/cm^2 ($\sim$480 psi) just compensates for the effect of 1° C. (1.8° F.) temperature increase on viscosity, has been taken as the average of a large number of published viscosity-pressure data, and should only be regarded as a "rule-of-thumb" figure. Burwell[84] developed a fairly complete formula for the calculation of the load-carrying capacity of journal bearings which takes into account both the temperature and pressure coefficient of viscosity. Using a temperature function of the form $\eta = \eta_o/(A + \Delta t)^m$ he obtained

$$e^{\alpha_v P_{max}} \cdot \alpha_v P_{max} = \frac{\alpha_v B^2 (\Delta t)^{2\alpha} (A + \Delta t)^m}{\mu K_1 K_2 D^2 N^2 \eta_o} \qquad (21)$$

where: P_{max} = maximum load that can be carried per unit bearing area, D = diameter of shaft, N = revolutions per unit time, K_1 K_2 = constants depending on the bearing dimensions, $B_1\alpha$ = empirical constants depending on the heat transfer characteristics of the bearing.

Charts for numerical evaluation of equation (21) are given in reference ([84]). Consideration of the viscosity-pressure effect will lead to the highly desirable use of lower viscosity oils than "classical" bearing formulae would permit. Burwell[84] pointed out that e. g. an SAE 10 oil at 5000 psi has the same viscosity as an SAE 30 oil at atmospheric pressure (all other conditions being equal) giving, therefore, the same load-carrying capacity (at 5000 psi) but running much cooler!

All of the above reviewed theories of lubrication apply solely under conditions of full (or hydrodynamic) lubrication. The inclusion of temperature and pressure effects in their mathematical formulation led to a better understanding of many observations which had erroneously been ascribed to "oiliness," that is, surface interaction effects. The increasing use of high polymers in lubricating oils will in the near future require that allowance be made for the viscosity-reduction due to flow orientation, characteristic of such blends. We see that the number of physical constants of lubricating oil which enter into bearing calculation is increasing rapidly, from the single one (η) a few years ago, as the operating conditions of bearings increase in severity.

Boundary lubrication qualities of lubricants have been conclusively proven as due to physical and chemical adsorption effects and will therefore be treated in the chapter on Phase-Equilibria.

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Industrial Emulsions

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("Oel u. Kohle," No. 19-20; May, 1943)
Translated by Edwin J. Barth, Petroleum Technologist

A SERIES of emulsions are described useful for the metal-working industry, such as for metal cutting, grinding, boring, etc.

New emulsifiers, and procedures for preparation of the emulsions and composition of the products are given. In one series of tests it was shown that when making mineral oil emulsions it appears that greater amounts of emulsifier are consistently needed as the viscosity of the mineral oil increases.

In a second series of tests it is shown that certain "inherent polar bodies" present in commercial and especially in unrefined oils greatly aid in obtaining good emulsions. It appears that with such oils the emulsifier functions more efficiently. No stable emulsions are possible (over several weeks standing) with highly refined oils using the normal amount of emulsifier. The quantity of emulsifiers used are already quite high.

In a third series of tests we show the relation between stability and type of dispersions when the system graphite plus oil is emulsified. Several procedures for preparing graphite-emulsions for the metal-working industry are referred to.

EMULSIONS are composed of finely divided materials which are either liquids or soft solids of semi-fluid variety in mineral oil or, most commonly, in water as the external phase. The finely divided materials are those which do not actually dissolve in the outer or external phase, such as water.

The emulsifying agent, or the "go-between" for the dispersed particles and the bulk fluid, are the "emulsifiers." They cause the fine particles to remain discrete and prevent them from coalescing. The emulsifiers usually are soaps or soap-like products.

For purposes of our discussion letters may be used to specify the various components comprising emulsions. We distinguish the following groups:

M, the divided or dispersed material, called the "inner phase" or "disperse phase." In our case here this becomes the mineral oil to be emulsified which must exist in the form of very fine particles of liquid or may also be a resinous plastic substance.

E, the emulsifier or "disperser," which is responsible for the emulsion. It is usually a soap or may be added as the unfinished soap in the form of its constituents S and B.

As constituents for such soaps we may have:

S, the acids, mainly organic or fatty acids or materials similar to these, such as rosin acids, sulphonic acids or sulphonates, and a great variety of saponifiable substances.

B, the bases, sodium, potassium, ammonia and other alkalies.

L, solvents or "introfiers" which may be added to aid in certain solubility or plasticizing effects—the alcohols, hydrogenated phenols, hydrogenated naphthalene, and the like.

W, this is the third main component of emulsions—also called the dispersion medium, "outer phase" or "closed phase." This is the medium which contains the "inner" or "dispersed phase," which is properly surrounded with an adsorbed or attached coating or film of the emulsifier. These particles float or are very finely suspended in this "outer phase," which is usually water.

The average cutting oils, bore oils and grinding oils used in the metal industry very extensively are really colloidal solutions of E in M or M in E; they usually can be diluted with water, where the emulsifier is water-soluble but they should not be erroneously called "water-soluble oils."

There are two procedures which may be used to produce water-dispersible or oil-in-water emulsions:

1. The emulsifier E is inherently built up in the mineral oil M from its components S and B. The advantage here is that since the components are well soluble in the mineral oil the soap forms readily by reaction and it also is soluble and completely in solution in the oil. Such a built-up soap is now readily available for physical action on the "internal phase." The mix M plus E may, however, not be well dispersible or clearly "water-soluble." Often in this procedure we are forced to use solubilizers, L, as an aid for real emulsification, and then to adjust carefully the pH by means of S or B into the range of favorable pH values for nearly all emulsions. This range is 6.7-8.4. This is necessary to obtain very finely divided emulsions stable over long periods (storage stability). Such products are homogeneous milky emulsions of M + E in W.

2. The emulsifier E, as under present practice will be one substantialy soluble at once in the mineral oil, and the latter may be, conversely, also soluble in it. Clear and transparent products of this type are easily "soluble" and permanently stable in water. Occasionally, one may note, however, that the solution M + E is cloudy or that E will thicken M unduly. Emulsions of such cloudy or unduly thick solutions of M + E will be found later to be none too stable in water. If further tests are made one will find that the cloudy product will have separated into layers after standing several days, which is absolutely objectionable. The lighter mineral oil will compose the upper layer; it may contain some emulsifier. This layer is no longer emulsifiable. In the lower layer one will find the bulk of the emulsifier having separated, containing perhaps a little of the mineral oil. In most cases the separated layers can be reworked or homogenized. Usually, it will be found best to adjust the system with very small additions of either more S or B in order to obtain an absolutely clear stable product, which will give good stable emulsions of M + E when dropped into W.

The finished watery emulsion (M + E) + W consists of a network of droplets M (all covered by a film of E) in W. If the emulsion is to be storage-stable to any degree the average oil droplets should measure not over 5μ (0.005mm) and it is important

gasoil furnishes at once a clear stable solution or product, but it does not emulsify well. This may be due to the high acid number of this gasoil (5.1). The emulsions become absolutely stable by the addition of traces of ammonia to bring the pH value to 8 or over.

In the system 14 percent E-70 and 86 percent SO_2—extract one would expect good stability according to Stokes law since the difference in densities is small. The oil product is clear and stable but the emulsions in water are unsatisfactory. The reasons for this are not quite apparent to us at this time especially since we took great care in removing the last traces of SO_2 gas from the oil. No doubt the extract contains a preponderance of foreign substances not ordinarily found in a commercial lubricating oil. Resins and polymers in such extracts probably call for a greater proportion of basicity than happens to exist in the common emulsifiers.

The mixture 14 percent E-70 and 86 percent M-SO_2 extract oil, clear in itself, does not emulsify satisfactorily. The reason here would be that light specific gravity and heavily refined products need different quantities of emulsifier than we used here. The same applies for mixtures with M-A pale oil, M-885 oil, and M-regular.

Fourteen percent E-70 and 86 percent M-nitro-raffinate gave turbid mixtures, which soon stratified, and did not emulsify. This is due to the high viscosity of the oil which demands larger quantities of emulsifier. The same applies to the M-Galician oil. However, in the last case raising the emulsifier to 20 percent gave A-1 emulsions in water. Twenty percent emulsifier, however, added to the M-nitro-raffinate was of no avail since here, as we have said before, the solubilizing polar materials have been removed from the oil by drastic refining. A discussion of the nature of these substances will be dealt with in another paper.

In a third series of tests we sought to test out ideas on stability of cutting emulsions in comparison with dispersions of so-called colloidal graphite. In order to obtain good graphite dispersions in mineral oils it is of great importance that the oil contain "solubilizers" or "peptizers"—polar or resinous constituents, etc. Materials of this type peptize the colloidal graphite particle by acting as protective colloids. Commercial colloidal graphite-oleosols made up in petroleum distillates, treated or untreated, are quite stable for long periods, while those made up with white oil, "liquid paraffin," in solvent raffinates or in synthetic oils show early and rapid sedimentation. It is very clear that the last mentioned oils lack some substance which aids in wetting the graphite and prevents sedimentation by keeping the particles "protected" and in motion. When colloidal graphite is ground up with oils: M-D10, M-Tp, M-Rouman, and the M-Gallician oils, the dispersions showed very good stability, while the following gave unsatisfactory stability: M-D20, M-SO_2 extract, M-SO_2 raffinate, M-nitro raffinate, M-A pole, M-885 and M regular. The white oil and synthetic oil were without effect and the graphite settled out at once.

We started another series of tests to investigate the addition of colloidal graphite to the system (M + E) + W, in order to make the usual cutting-oil mixtures useful in reducing friction and which are known to give smooth metal finish. For this purpose colloidal graphite is used in the form of an oleo-sol, such as "oil-DAG," "Kollag," "Grasinol," and some

TABLE 3
Mineral Oils Used in Series No. 3 Tests

OIL USED	d/20	n_D/20	E-50	m	Wp	Flash	Pour	Ac. No.	Sap.No.
m—(H_2SO_4) Raff.	0.910	1.508	2.5	3.95	2.08	190 C.	—22 C.	0.05	0.12
m—Distillate.	0.927	1.520	3.6	4.11	2.76	192	— 5 C.	0.45	0.62
m—Solvent Raff.	0.948	1.532	10.0	4.05	3.14	215	— 8 C.	0.14	0.34

of the I.G. preparations on the market; hydro-sols can also be used: "Kohydrol," "Hydrokollag," etc. It is apparent that the graphite oleosols must first be mixed with the mineral oil in order to prepare the M + E base, since the presence of the emulsifier influences the colloidal nature of graphite to some extent, at times adversely. There is no object in preparing the bases by mixing the graphite sols with an aqueous emulsifier when the graphite oleosol is specifically prepared to be suspended solely in oil. Where the graphite hydrosols are used it is understood that the base is later to be diluted with water before use.

The second procedure would appear to be the more feasible method for making "water soluble" graphite suspensions. The bases so prepared are normally diluted with water in metal plants just before use.

The mineral oils used in this group of tests—stability of colloidal graphite suspensions—are tabulated in Table 3. The emulsifier used was E-41.

Mixtures of 22 percent E-41 and 78 M-Sulphuric acid raffinate (M-distillate) showed stable clear oil solutions with excellent emulsifying properties. The solvent-raffinate of viscosity 10.0E at 50° C. necessitated the use of 28 percent E-41. In preparing the colloidal graphite suspensions 4 percent of Kollag (an I.G. graphite oil concentrate) was ground into the above three oils, and adding (stirring) the emulsifier in last. The tests showed that dilution of the graphite oleosol (0.4 percent graphite contents) with the emulsifier resulted in a good smooth homogeneous suspension. There was no apparent or visible floculation of the graphite whatever in the first few days but there were indications of this later.

The system (M + G) + E + W, when freshly prepared furnishes emulsions of a grayish color with very high dispersibility and fineness of particle size so that one may expect good stability and suspension of the graphite almost indefinitely, especially since these mixtures are kept in circulation in the average metal-working shop. When these grayish emulsions are allowed to stand quietly, however, they do change considerably. After a short period, black floes appear and a thick creamy layer of bluish-black color layer has separated. The coarser graphite particles meanwhile deposit at the bottom of the container. A light grayish emulsion or mixture nevertheless remains, which contains the smallest particle size graphite in motion and suspension, and this intermediate material (the greater percentage of the original) remains stable after weeks of standing. As already mentioned, it is more feasible to employ the system (M + E) + (W + G), that is, suspending "Hydrokollag" or "Kohydrol." It appears that graphitized oil emulsions in water will become increasingly more popular in the future, when their preparation is fully understood. Results obtained with these products in the metal-working industry leave little to be desired.

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[1] Tall oil, a by-product of the wood-pulp industry. It contained 10-45 percent rosin acids, 45-80 percent unsaturated fatty acids, and 5-10 percent sterols, all of high molecular weight.

[2] One should determine here interfacial tension oil/water rather than consider surface tension oil/air.

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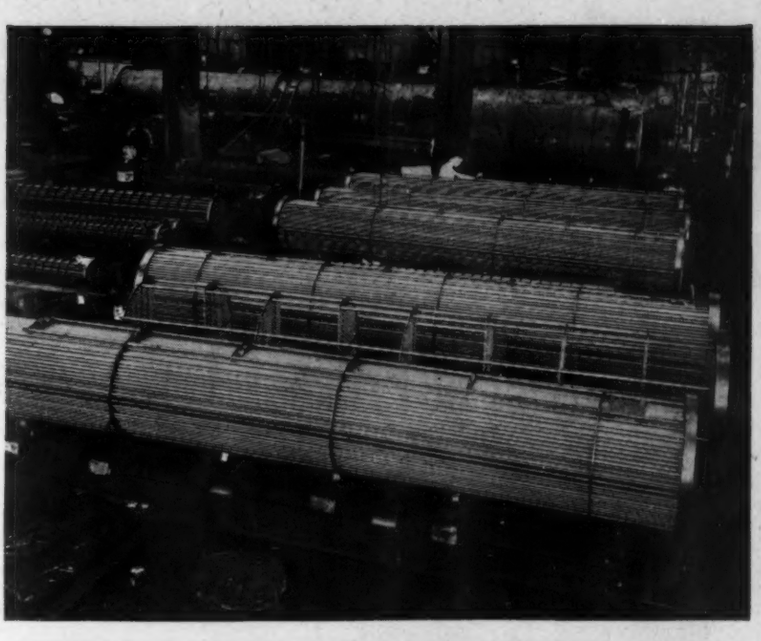

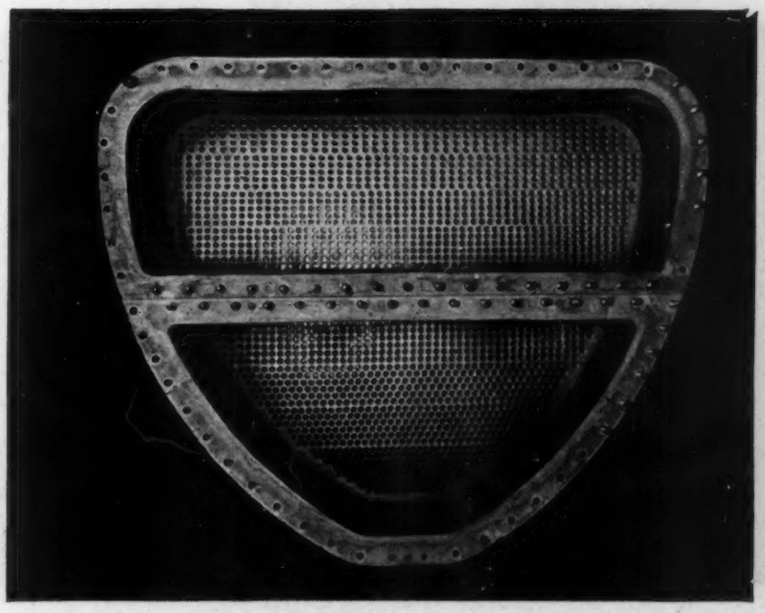

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OPERATION HOW TO DO IT MAINTENANCE

1. Rotary Gauge Indicates Hydrofluoric Acid Level in Process Vessel

THE principle of the rotary gauge is not a new idea, but its use for determining the location of the interface between hydrofluoric acid and hydrocarbons is comparatively new.

The rotary gauge herein described was constructed due to unsatisfactory results obtained from various other types of level indicators. Very satisfactory results have been obtained with the rotary gauge on process vessels and storage tanks containing HF acid.

When it was decided to construct the rotary gauges, the following points were kept in mind:

1. Accuracy of gauge tests.
2. Conservation of HF acid.
3. Ease of operation.
4. Safety.
5. Suitable materials.
6. Disposal of waste materials.

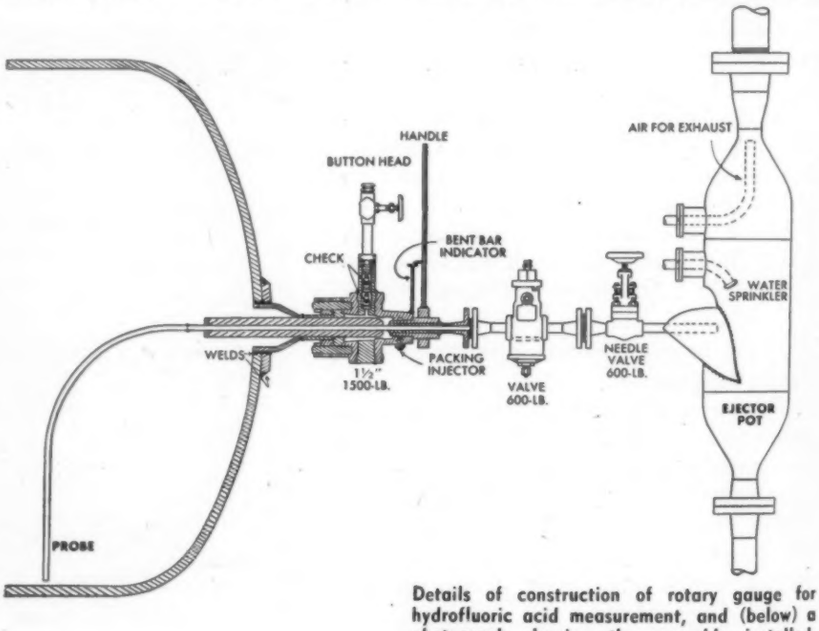
Accuracy of determining the location of interface of fluids depends on the operator. If the operator or gauger uses care he can locate within a small fraction of an inch where levels are in the vessel. The circular gauge scale can be graduated in percent of vessel volume, barrels of fluid, or in inches of depth in the tank or vessel.

Since HF acid is a costly processing material, it should not be wasted. Therefore, the fluid passageways through gauge mechanism should be kept as small as possible and yet not so small that they plug off when not being used.

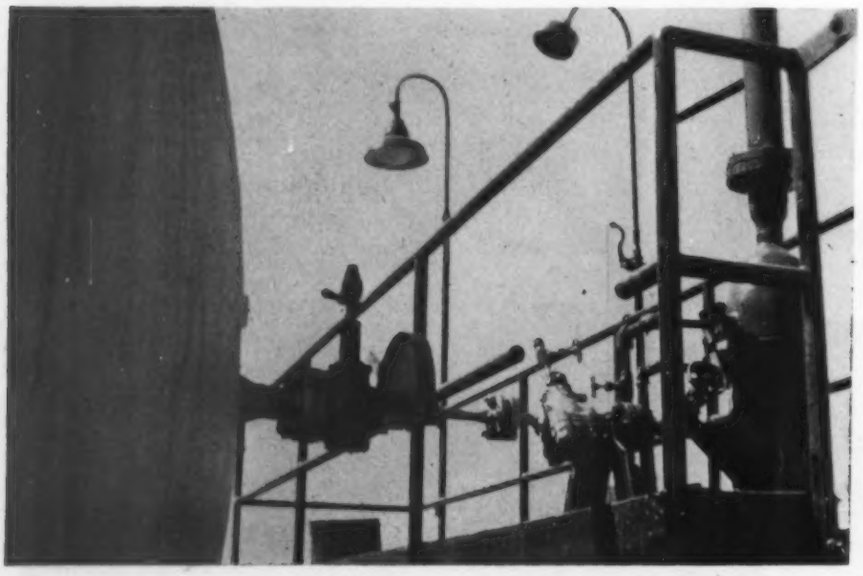
The operation of the gauge should not be difficult, and should as well be safe, for the operator. A threaded packing stem lubricated plug valve was found to provide a positive type of shut-off packing, when a fibrous type of grease is forced into the threads, as well as providing rotary motion.

Mild carbon steel is commonly being used to handle HF acid with moderate success, when the acid is maintained at high concentrations. Monel has proved to be a more desirable metal over a considerabel range of acid concentrations, due to its corrosion resistance and the absence of scale formations building up on the metal surface. It was, therefore, decided to select discarded 1500-pound 1½" socket welded plug valves, in order to save a considerable amount of machine work. The probe tube and tube guide are both made of Monel, since these are the working parts in contact with the acid. All other parts of the gauge can satisfactorily be made of carbon steel.

The rotary gauge nozzle on the vessel is made from 4 x 2-inch Schedule 80 swedge, having a special flange on the 2-inch end made to fit base of 1½-inch valve. In order to have the gauge mechanism removable, the probe tube guide is welded to a filter plate, which is located between nozzle flange and the valve base.



Details of construction of rotary gauge for hydrofluoric acid measurement, and (below) a photograph showing the assembly installed.



The swedge provides a sufficiently large opening in the vessel to allow the bent portion of the probe tube to enter the vessel. One of the pipe connections on the 1½-inch valve is plugged and welded shut. In the other pipe connection is inserted a double check lubricator connection having a steel needle shut-off valve and button-head lubricator. This is to provide a sealing lubricant into the inner part of the mechanism.

Try cock valves on the outlet end of the probe tube are, first a shut-off block valve, followed by a needle or globe type of throttling to make the probing test. Both the block and throttling valves should be Monel or Monel trimmed.

To safely observe whether HF acid

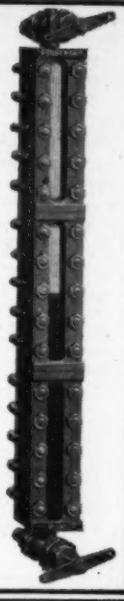
PENBERTHY

"REFLEX"

DROP FORGED STEEL LIQUID LEVEL GAGES

Liquid always shows black—empty space shows white. Preferred where the liquid level must be easily and positively visible, and when liquids are under high pressure or at high temperature. Made of alloy temperature resisting steel and are highest quality throughout. Liquid chamber made from solid block of steel to assure perfect alignment and rigidity. Conform with A.P.I.—A.S.M.E. requirements.

The "Reflex" is one of the complete line of Penberthy Gages that meet every liquid level gage requirement.

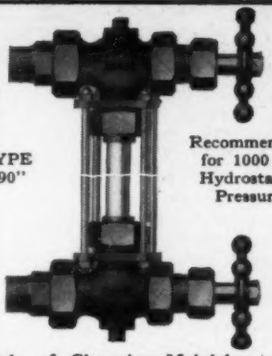


PENBERTHY INJECTOR CO.

DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

DROP FORGED STEEL LIQUID LEVEL GAGES



TYPE "90"

Recommended for 1000 lb Hydrostatic Pressure

Made of Chromium-Molybdenuin alloy temperature resisting steel, extra heavy throughout and stainless steel trimmed. Positive automatic shut-off; stainless steel balls shut off the flow of liquid if glass breaks. Regrinding removable seats, heavy duty stuffing boxes, union connections. Conform with A.P.I.—A.S.M.E. requirements.

This is one of the complete line of Penberthy gages that meet every liquid level gage requirement.

PENBERTHY INJECTOR CO.

DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

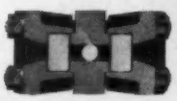
PENBERTHY

"TRANSPARENT"

DROP FORGED STEEL LIQUID LEVEL GAGES

Used to observe color and density of liquids under high pressures and/or temperatures. Construction exceptionally sturdy. Made of alloy temperature resisting steel, and are highest quality throughout. Liquid chamber made from solid block of steel to assure perfect alignment and rigidity. Conform with A.P.I.—A.S.M.E. requirements.

The "Transparent" is one of the complete line of Penberthy gages that meet every liquid level gage requirement.



PENBERTHY INJECTOR CO.

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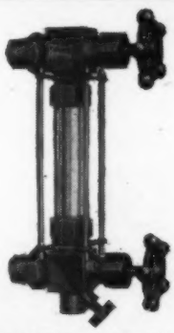
PENBERTHY

"ALL IRON"

LIQUID LEVEL GAGES



Body made from a special high strength alloy iron, shanks alloy steel and trim stainless steel. Extra heavy construction throughout, automatic and positive shut-off if glass breaks, heavy duty stuffing boxes. Conform with A.P.I.—A.S.M.E. requirements.

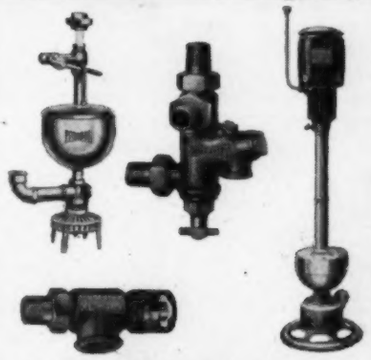
The "All Iron" is one of the complete line of Penberthy gages that meet every liquid level gage requirement.

PENBERTHY INJECTOR CO.

DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

QUALITY PRODUCTS



Penberthy injectors—ejectors—automatic electric and water (or steam) operated sump pumps are all widely used throughout the oil industry because they have always been dependable under the most severe service conditions.

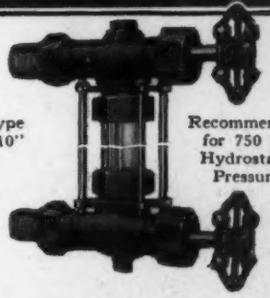
All are of rugged construction and made by an organization with 59 years experience in the manufacture of highest quality products.

PENBERTHY INJECTOR CO.

DETROIT 2, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

DROP FORGED STEEL LIQUID LEVEL GAGES



Type "10"

Recommended for 750 lb. Hydrostatic Pressure

Steel construction throughout with stainless steel interior trim. Automatic shut-off is positive and instantaneous; stainless steel balls shut off the flow of liquid when glass breaks. Heavy duty stuffing boxes, union connections, offset construction facilitate cleaning and simplify glass replacement. Conform with A.P.I.—A.S.M.E. requirements.

This is one of the complete line of Penberthy gages that meet every liquid level gage requirement.

PENBERTHY INJECTOR CO.

DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

or hydrocarbons are released when making the probing test, an exhauster type trap was entirely fabricated from steel pipe and pipe swedges. Air is used in the exhauster jet, because it helps to dilute as well as pull out the acid vapors and does not saturate them with water vapors, as when steam is used. The vent stack extends six or eight feet above operator's head. The top end of the stack is turned sideward at about 45° and may be rotated to vent the HF gas with the wind and thus be carried away as fast as possible.

A water spray is provided just above the pitcher-mouthed opening receiving the liberated HF vapors. This spray scrubs the vented vapors and washes any acid or hydrocarbons in the liquid state down the bottom drain which goes directly to a neutralizing pit.

Several months' operation of this equipment has given very satisfactory and desirable results. It may later be found that materials used in the fabrication of the exhauster should be changed to copper or Monel.

2. Horizontal Gas Cooler At Cycling Plant

ON A plant where it was discovered that the temperature of gas from the wells was much higher than expected, due to the high formation temperature, a simple but effective remedy was affected by installing gas coolers. Since the header from the separator and meter installation was strung out on the ground, a simple hookup was devised by installing a set of condenser tubes parallel to the gas header. By making a flanged connection on the end of the header opposite the absorbers, the gas was rerouted through the coolers and the temperature reduced by means of cold water.

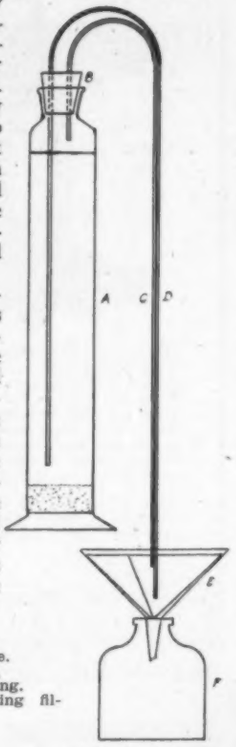
During periods when the outside temperature is sufficient to cool the gas, it can be routed directly to the absorbers.

Formation heat is reduced to required operation temperature by routing the gas through coolers.

3. Controlled Flow for Laboratory Filter

THIS method was devised by a laboratory technician when confronted with the problem of filtering large quantities of a fluid which ran through the filter paper very slowly, necessitating the refilling of the filter many times a day. It is especially adaptable to those supernatant solutions which must be siphoned off a precipitate because of the disturbance caused by decantation.

Using the simple apparatus shown in the figure, considerable time is saved and it requires no attention once the siphoning action is started. The filter cannot overflow because when the liquid in the filter reaches the glass tube C, the source



LEGEND
A—Mixing graduate.
B—Rubber stopper.
C & D—Glass tubing.
E—Funnel supporting filter paper.
F—Receiver.

of air for displacement of the fluid in A is stopped. Liquid immediately rises in C to the same level as in A and then siphoning is retarded until the level in the filter is almost to the bottom of glass tube D at which time the weight of liquid in D is sufficient to withdraw the lesser amount in C into the mixing graduate A. The operation is then automatically repeated until the level in the graduate has been lowered to the intake of tube C.

Win a Bond

EACH month the operating personnel in the refining, cycling and natural-gasoline plants determine the winner of a War Bond, maturity value $25.00.

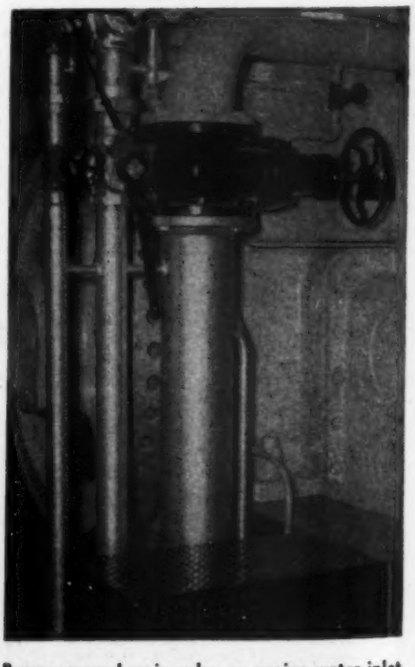
Superintendents, assistant superintendents and foremen (subscribers as well as non-subscribers) become a jury to select the most practical contribution to this department on maintenance and operation. The editors rotate voting among men qualified to determine the rating.

This award is in addition to payment for the article. The methods of solving plant operation and maintenance problems come from the personnel of the industry. Items provided by Petroleum Refiner staff members will not be eligible.

Send contributions to Petroleum Refiner, P. O. Box 2608, Houston 1, Texas.

4. Cooling-Water Bypass For Engine Safety

ONE engineer provides against accidental emptying of the water passages in the engine by running a small bypass line around the main valve controlling the inlet to the engine jacket. Since the



Bypass around main valve on engine water inlet. Bypass for main valve on engine water inlet.

delivery or inlet side of the water-circulating system is under pump pressure, and efflux is by gravity, cracking of the small bypass valve will insure a flow through the engine sufficient to maintain losses and to provide evidence at the tell-tale that the jacket is full of water.

Use of the bypass to maintain desired water level results in the gradual cool-

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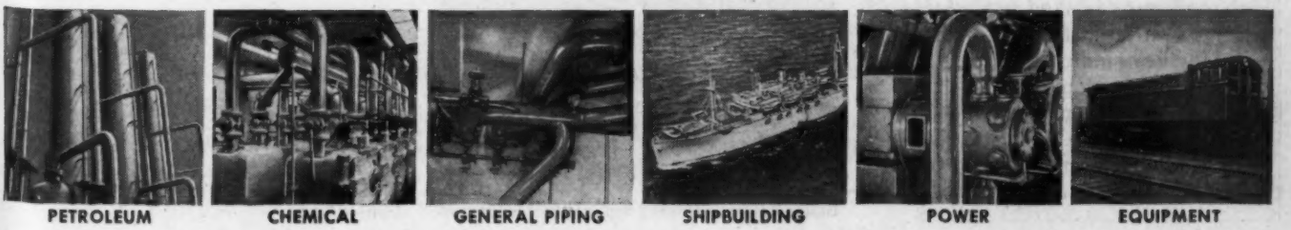
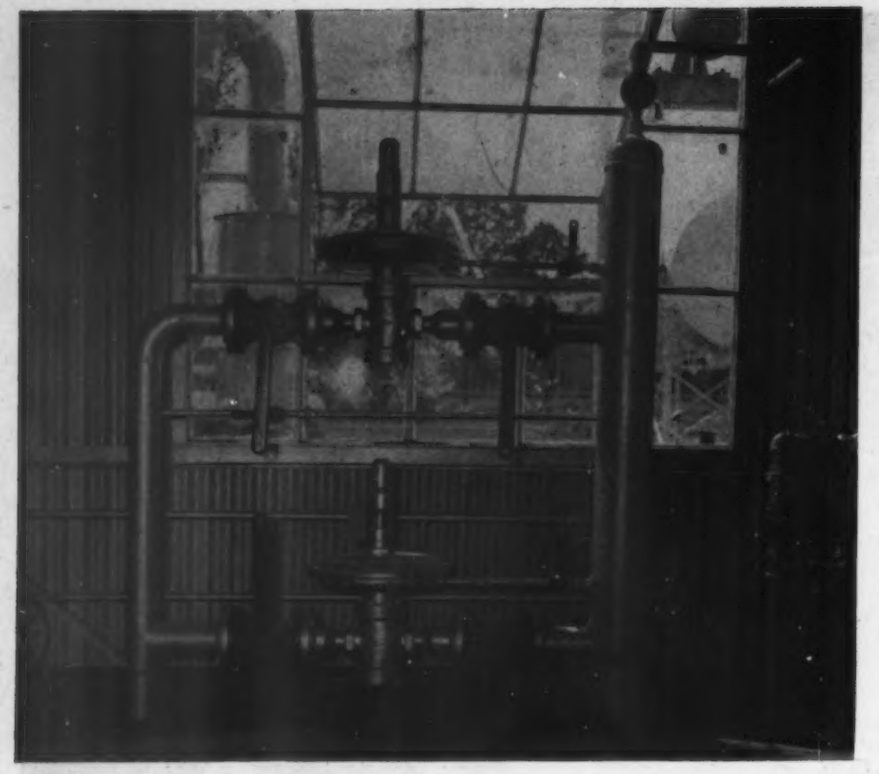


PETROLEUM | CHEMICAL | GENERAL PIPING | SHIPBUILDING | POWER | EQUIPMENT



This arrangement of gas pressure regulators saves floor space and permits access for servicing.

ing down of the engine after fuel is cut off—instead of the sometimes destructively rapid cooling experience if the flow is checked by pinching down on the main control valve.

With the bypass valve open only when starting up after a long shutdown, the engine can be warmed up in much less time than when the main valve is used to control coolant flow. The saving in power thus effected reduces stand-by loss, while the better lubrication cuts the maintenance.

5. Rod Holder Protects Pump-Rod Packing

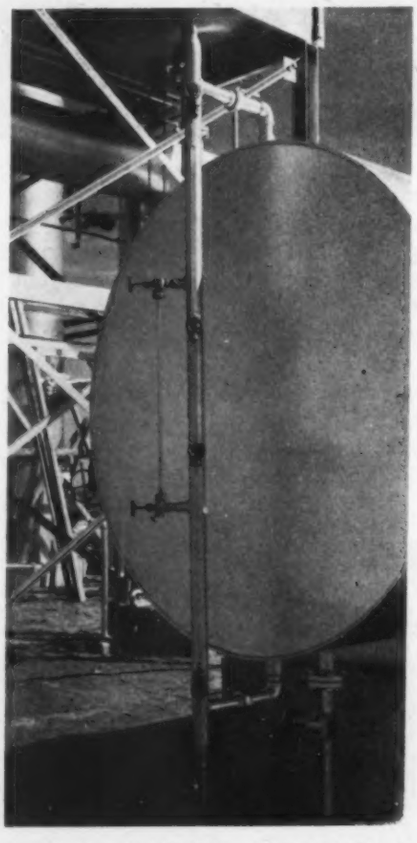
PROTECTION of pump-rod packing requires more than the cardboard shipping box in which the packing comes from the manufacturer, as the engineer rarely has space in the tool box for the box, nor does it have rigidity enough to withstand contact with tools and other equipment thrown into the bin.

One engineer has rigged up a set of pipe nipples, slightly smaller than the rod for which the packing is designed. The packing is strung on these nipples, a flanged washer at the bottom of the holder preventing the set from sliding off.

When repacking a rod, the holder is suspended to bear the job, and it is easy to slip off the rings as they are needed.

THE WINNER

A number of readers selected at random and asked to evaluate items printed in this department in May have indicated the award should go to Item No. 1—"Proportioning Pump Powered by Take-Off." This item was contributed by a member of our regular staff.



Gauge column attached top and bottom of tank.

6. Dual Regulator Voids Plant Shutdowns

ONE plant reduces the floor space required for gas pressure regulators and at the same time facilitates repair or replacement of either regulator by setting them in parallel vertically instead of horizontally. Both inlet and low-pressure risers serve as supports for the setup, with valves on each branch to permit isolation of either regulator as desired. Clearance is afforded over the lower unit to enable adjustments to be made without interference with the upper unit.

Between the two branches which carry the regulators, a ½-inch line is tied across between the risers, with a needle valve which in emergency permits flow of a small quantity of high-pressure gas directly across to the low-pressure system. With this provision, the plant is assured of fuel enough for power requirements, even though the two regulators are out of service.

7. Raschig Rings Dumped In Tower Undamaged

RASCHIG rings used for packing in absorption and distillation towers are often fragile, and some plants have experienced high percentages of breakage while dumping these rings into towers.

One California company has stopped this breakage in its plant in a novel manner. All openings of the tower to be packed are closed except for a manhole or filling connection at the top of the vessel, and the tower is then filled with water. The packing is then dumped into the tower in small batches, the water serving to cushion the fall of the packing and prevent breakage. This arrangement may be used for any packing material which is not damaged by water.

8. Mounting Gauge Glasses Without Stresses

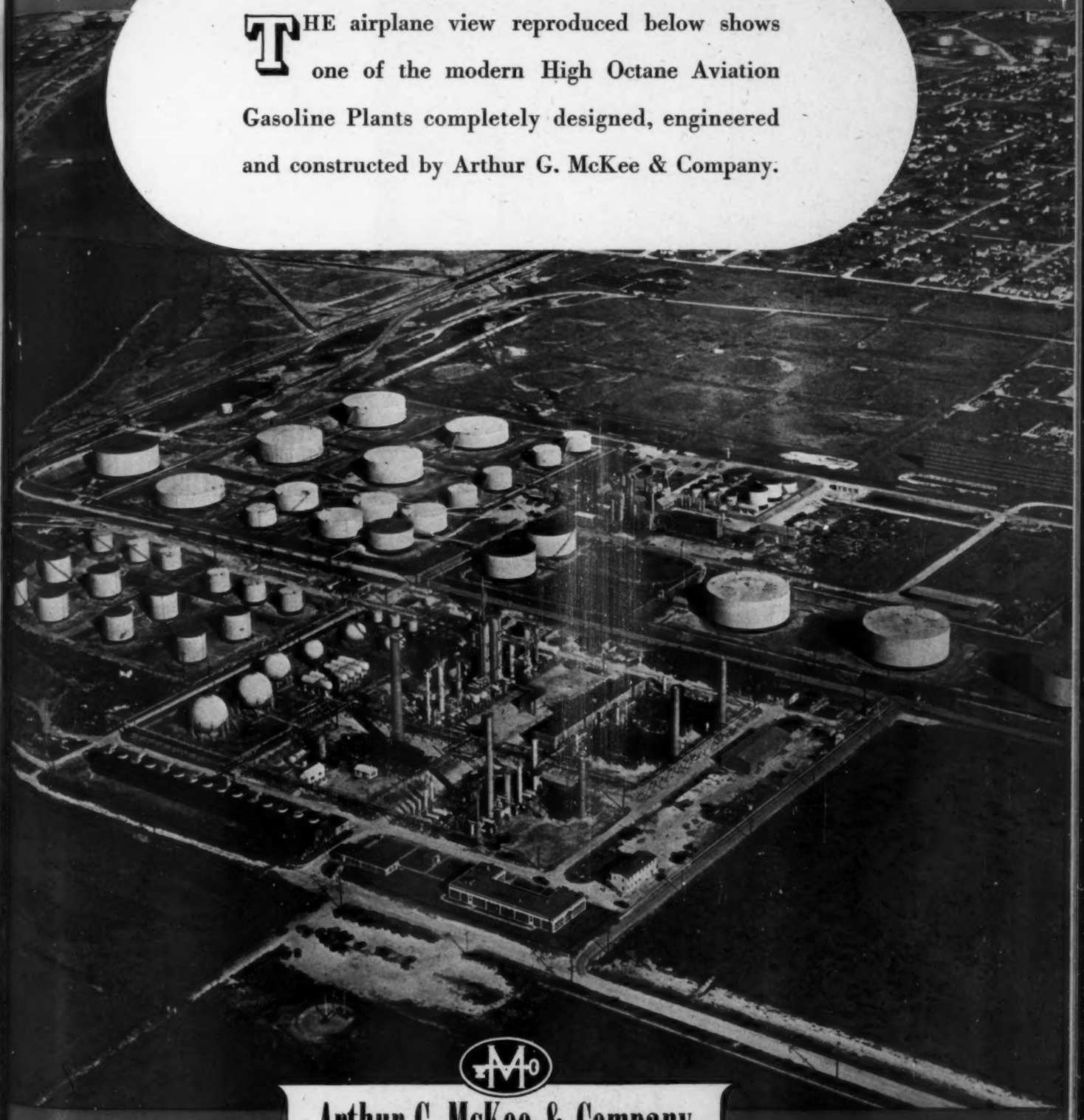
PROTECTION of the gauge glass on the end of a cylindrical tank against stresses set up by change in tank shape through expansion or change of liquid level is obtained by one engineer through the expedient of attaching the glass column to nipples welded to top and bottom of the tank. Unions in the horizontal runs to the column facilitate assembly, and compensate for slight misalignment of the fittings welded to the tank.

The glasses themselves are supported on short stubs welded to the gauge column, the three sections of the glass tube being set so that any one may be withdrawn without contacting the other two.

The horizontal connecting sections, with the ground-joint unions, permit considerable change in tank dimensions

UNDIVIDED RESPONSIBILITY IN ONE ORGANIZATION

THE airplane view reproduced below shows one of the modern High Octane Aviation Gasoline Plants completely designed, engineered and constructed by Arthur G. McKee & Company.



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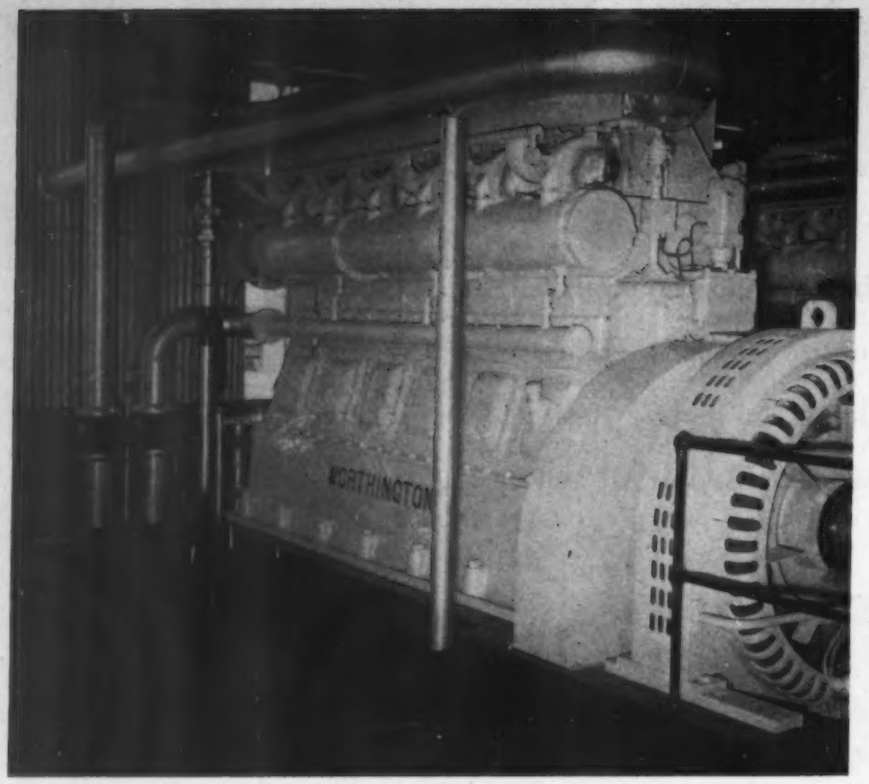


The exhaust pipe support (center) is flexible enough to not interfere with heat stresses.

without affecting the column, while the gauge tube itself is sufficiently heavy and rigid to afford ample for the glass tubing.

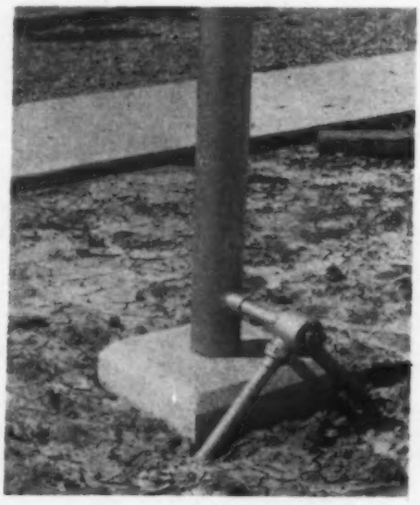
A swage and valve at the base of the liquid column permits draining away of any water which may tend to collect at this, the lowest point of the system. Each glass section is provided with individual drain, so that fluid may be vented when a glass is to be changed or repacked.

9. No-Short Connection For Light Standard

WHEN pipe standards are used for supporting yard lighting fixtures, the tube is generally utilized to carry the wiring from the underground conduit to the top of the pole. In areas subject to much rainfall, connection of the conduit to the pole must be checked to prevent moisture from entering the line and shorting the circuit. This plan also requires excavation in the yard if the wiring is to be checked.

One plant obtains access to the pole well above the water line by welding on a pipe nipple, carrying a waterproof junction box with two outlets on the end of a stub just long enough to clear the concrete pole base. Instead of making connection to the conduit below ground, the pipe is brought above the surface, and connected through a 45-degree angle to the two outlets of the junction box. The two angles are so placed as to be at ground level at the edge of the concrete post base.

A plug which closes the outer end of the junction box permits examination of the wiring without breaking any of the other joints in the hook-up as well as facilitating replacement of wiring when necessary.



Light standard tie-in placed above water level.

10. Exhaust Support for Multi-Cylinder Engine

PROVISION of an outside support for the exhaust line of a multi-cylinder engine driving one generating unit, instead of carrying the weight of the line on the flange fitting at the end of the exhaust manifold, relieves the engine of much weight, and also minimizes the effect of engine vibration on the long exhaust pipe.

The exhaust line is supported on a 3-inch pipe post, this being so set as to avoid interference with the manhole cover plates of the crankcase assembly. The post is set into the concrete floor, so as to insure rigid support. At its top is mounted a saddle, formed to the contour of the exhaust line. After the line is assembled in place and the flange bolts are drawn tight, the saddle is welded to the pipe, so as to prevent overturning or twisting effort in the pipe through the curved return bend to the manifold outlet.

When the exhaust line must be removed for any reason the flange connection is broken, and the pipe with its post then lifted enough to enable the post base to clear the socket in the concrete —the line then being lifted as a unit and laid aside until reinstalled.

11. Filter Cistern for Makeup Water

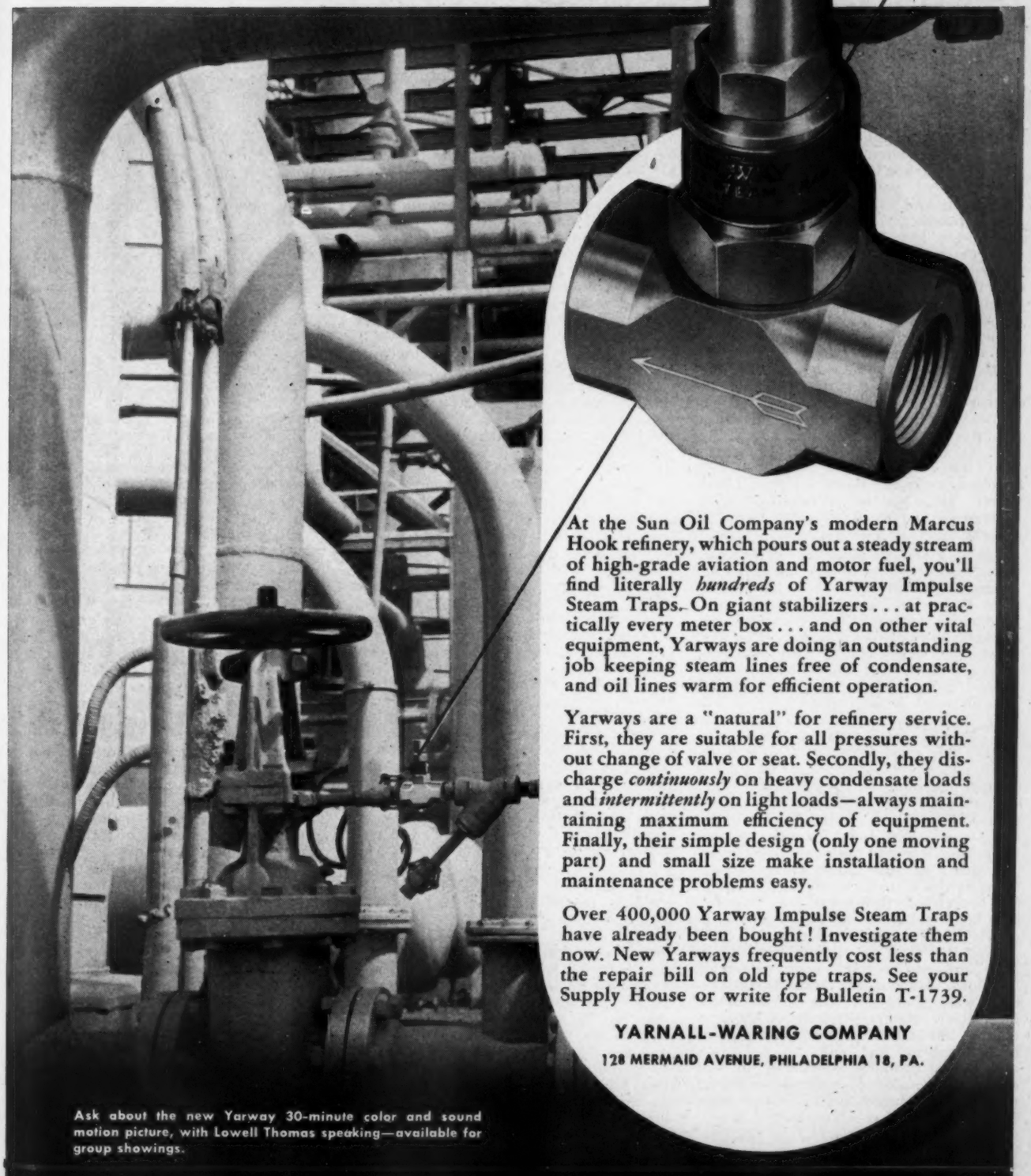
IN AREAS where available water is not suited for circulating through engine-cooling systems, or where it must be hauled in by tank for considerable distances, collection of the rain which falls on the roof frequently offers an easy solution of the water problem.

One plant utilizes the corrugated roof of its power plant as collector for rain water, leading it through downspouts to underground storage where evaporation is minimized. The downspouts terminate in ingenious concrete filters, from the sides of which are led out the lines for transferring water to storage. The filter pits are filled to a depth of about 24 inches with pea gravel, washed clean before being placed. This gravel serves to trap trash which accumulates on the roof.

A frame, welded up from pipe, spans the manhole to the filter and supports a chain block which enables the gravel to be hoisted from the pit and either cleaned or replaced when inspection proves the need of a change in the filtering medium.

READERS ARE URGED TO CONTRIBUTE items to this department. Drawings or photographs are desired where practical. Payment for items accepted will be on a basis that will compensate for the time involved and in addition each contribution will be eligible to receive the bond award as outlined in the announcement on page 140. Jury awards will be announced in the second issue after publication.

Hundreds OF YARWAY TRAPS GET A PLACE IN THE SUN REFINERY



At the Sun Oil Company's modern Marcus Hook refinery, which pours out a steady stream of high-grade aviation and motor fuel, you'll find literally *hundreds* of Yarway Impulse Steam Traps. On giant stabilizers . . . at practically every meter box . . . and on other vital equipment, Yarways are doing an outstanding job keeping steam lines free of condensate, and oil lines warm for efficient operation.

Yarways are a "natural" for refinery service. First, they are suitable for all pressures without change of valve or seat. Secondly, they discharge *continuously* on heavy condensate loads and *intermittently* on light loads—always maintaining maximum efficiency of equipment. Finally, their simple design (only one moving part) and small size make installation and maintenance problems easy.

Over 400,000 Yarway Impulse Steam Traps have already been bought! Investigate them now. New Yarways frequently cost less than the repair bill on old type traps. See your Supply House or write for Bulletin T-1739.

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Ask about the new Yarway 30-minute color and sound motion picture, with Lowell Thomas speaking—available for group showings.

YARWAY IMPULSE STEAM TRAP

Petroleum, Natural Gas And Agriculture

DR. GUSTAV EGLOFF*
Universal Oil Products Company

THE earth supplies petroleum, natural gas, and products of field and forest. The hydrocarbon materials derived from reservoirs of petroleum, natural gas, coal, peat, and oil shale are essentially stored products of past life processes. Ages ago, long before man's appearance on earth, a luxuriant vegetation flourished which gave rise to our vast coal deposits. Marine life was a source of our enormous underground deposits of petroleum and natural gas. The conversion of marine life into petroleum and natural gas may well be going on at the present time even at a greater rate than we are consuming them. Agriculture utilizes soil, water, air, and sun to continually produce food and other products. Petroleum, natural gas, coal, and oil shale constitute a resource in the United States that can produce gasoline, kerosine, diesel oil, lubricants, waxes, asphalt, and a host of other derivatives for at least 3,000 years at present rates of consumption.

The petroleum and agricultural industries represent enormous investments. About $15,000,000,000 covers the investment in the oil industry. This includes producing, transporting, refining, and marketing of petroleum and its products. Since the first well drilled in 1859, over a million have been drilled in the United States at an overall financial loss, although a few fortunate producers have made money. There are now 400,000 oil-producing wells in the United States. The average depth of these wells is about 7,000 feet, although they vary from a few hundred to over 13,000 feet. The deepest well drilled at a cost of over $500,000, to a depth of over 16,000 feet, was a dry hole. A web of pipe lines, long trains of tank cars and trucks, and fleets of sea-going tankers make possible the transportation of 1,700,000,000 barrels of crude oil a year to refining centers, and refined products to points of consumption. Refineries comprising the latest developments in chemistry and engineering occupy strategic locations. During the war $1,000,000,000 was spent in the construction of special refinery equipment for producing 100-octane aviation gasoline, lubricants, diesel fuel, and a host of new and special products needed in the war effort. The value of refined petroleum products produced in 1945 was over $4,000,000,000 at the refineries.

Farming is a still more gigantic industry than petroleum. The United States Department of Agriculture states that the investment in farm lands and buildings in the United States in 1944 was $45,592,000,000. The same source gives $8,604,000,000 as the cash receipts from farm marketing of field crops, and $11,186,000,000 from marketing livestock and its products.

Petroleum and farming are mutually interdependent. The petroleum industry utilizes a wide variety of farm and forest products. From the farm, oil-well drillers use sugar cane bagasse, wheat bran, and cottonseed hulls to plug porous underground formations. Starch is used to keep the constituents of drilling mud from settling on the bottom of wells. Hay is used in breaking oil field emulsions. The oil industry employs in its varied operations beeswax, wool for blankets and insulating hair felt, leather goods such as belting and gaskets, furfural produced from oat hulls, and all types of vegetable oils and animal fats. The army of oil workers in fields and refineries consumes enormous quantities of food products. To increase the wellbeing and profits of both industries, the American Petroleum Institute has formed a research and development committee in order to assist agriculture to produce more and better crops, and improved livestock and its products.

In refining and compounding oils and greases, many thousands of pounds of tall and tallow oil, lard oil, degras, oleic acid, glycerol, and other fats and fat products are needed. Stearic acid from animal fats is used in manufacturing candles and greases. Vegetable oils and resins obtained from pine trees are utilized in making greases, polishes, floor oils, and other specialties in amounts running into many thousands of gallons. Among forest products used in the petroleum industry are antioxidants for gasoline, cordwood, lumber, barrel staves, fiberboard, and paper pulp.

Farm Mechanization

Farm machinery produced in 1944 was valued at $664,000,000. Because of the extensive use of farm machines fueled with gasoline, tractor fuel, and diesel fuel, the annual labor requirements for producing corn in the United States are now 600,000,000 hours less than in the years from 1909 to 1913. The hours of labor per acre of corn dropped from 27.6 in the period from 1917 to 1921, to 22.5 in the period from 1932 to 1936. This occurred in spite of the fact that corn farming lends itself less readily to the use of motor power than wheat farming or other types. The advantage to the farmer in this decline of labor requirements is evident. He is able to produce his crops with fewer working days in the fields, and has time to maintain his home, barns, and machinery in better condition. Farmers now use 1,590,000 trucks, about one third of the nation's total, and in 1945 consumed 160,000,000 barrels of gasoline, one fifth of the oil industry's total production. At the present there are 2,200,000 tractors in use on American farms. Owing to the increased use of power-driven vehicles, the number of horses and mules on farms dropped from 26,000,000 in 1915, to 15,000,000 in 1942. This has resulted in more cultivated areas being turned to the production of cereal crops with more meat, milk, and dairy products available for human consumption.

Farm machinery is one of the important reasons why the United States was able to produce almost 50 percent more food in the last two years than during the comparable war years of 1917 and 1918. The amazing thing is that this increase was accomplished on about the same acreage and with some 4,000,000 fewer people at work on the farms.

The use of tractor-driven equipment in the various operations of field culture has markedly reduced costs. Comparative costs per acre when using horse-drawn and tractor-drawn equipment show that costs are less than half when using tractors than when using horses.

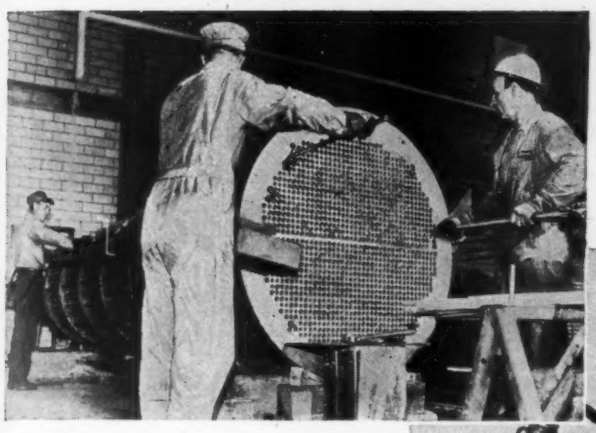
The use of trucks to transport farm products to market and manufactured products to the farm also changed the aspect of farm economics. Forty percent of America's 122,473 communities, which prior to the use of trucks had no good transportation outlets for their commodities, now are connected with a wide range of markets. Because of this transportation, farming can now be conducted in areas much further from markets. Better selection of farming sites and better distribution of farm products to the ultimate consumer is made practicable. Between 60 and 70 percent of all livestock and dairy products are now shipped by truck. The petroleum industry trucks its products to the farmer. In many areas a regularly scheduled supply of petroleum products is maintained so that the farmer does not have to store large quantities of gasoline, lubricating oils, greases, and other products. The farm is now thoroughly mechanized to these petroleum products. Petroleum products produced in the war effort, such as 100-octane gasoline, will find their way into agricultural use as rapidly as machines are designed to utilize them, which will cut still further the cost of producing farm products. Those who remember farm life as it existed realize the contributions which petroleum has made to agriculture and its economy.

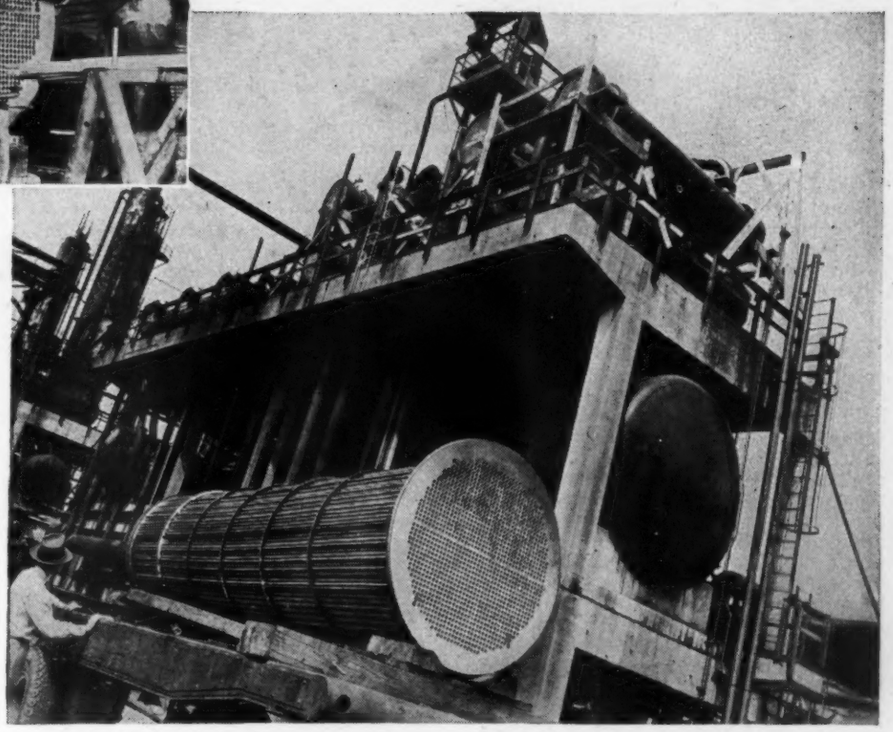
The petroleum industry supplies its lubricants and greases to the farmer for use in all types of machinery, such as tractors, harvester, threshers, trucks,

*Presented before the Second Southwest Chemurgic Clinic, Oklahoma City, Oklahoma, June 4, 1946.

Light Hydrocarbon from Fractionating Towers

handled by ANACONDA ARSENICAL ADMIRALTY TUBES...





(Above) Inserting Anaconda Arsenical Admiralty 439 Tubes in tube bundle at Houston, Texas, butadiene plant of Sinclair Rubber, Inc. Photograph at right shows tube bundle ready for installation in one of the shells on top of superstructure.

THE CONDENSERS shown in the photographs above are located at the butadiene plant of Sinclair Rubber, Inc., Houston, Texas. They were built to handle light hydrocarbon from the fractionating towers.

In order to provide the required heat transfer and economical service under the corrosive conditions encountered, the tubes being installed are Anaconda Arsenical Admiralty 439.

This Anaconda Alloy has been manufactured on a commercial basis since 1934. It is but one of 11 standard and several special condenser tube alloys currently produced by The American Brass Company.

This list provides tubes to meet a wide range of heat transfer requirements. The broad metallurgical knowledge and practical experience of our Technical Department is available in helping you make the right selection. 46174

ANACONDA

Anaconda

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THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company

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and automobiles. Our farmers use 75,000,000 gallons of lubricating oils and 85,000,000 pounds of greases annually. Before the advent of the petroleum industry, the farmer used bacon rinds and tallow oil for lubricating the axles and cup greases based on petroleum. During the war new types of super lubricants were developed which can now be obtained for the more efficient lubrication of farm machines.

In the manufacture of special greases, the petroleum industry consumes many tons of vegetable and animal oils. It uses oils such as castor, cottonseed, flaxseed, linseed, soybean, and sassafras, all produced on farms. Lard oil from pigs, stearine from cattle and horses, and tallow oil from sheep are also used. Over 100,000,000 pounds of tallow oil is consumed annually by the petroleum industry in the manufacture of greases. The United States Department of Agriculture estimates that this amount of tallow oil requires the slaughtering of 33,000,000 sheep. Similarly, lard oil used in compounding petroleum lubricants is a by-product of 1,000,000 pigs slaughtered annually. Many petrolum lubricants and greases contain as much as 20 percent of non-mineral oils.

Petroleum greases and oils are used for smearing the hides of hogs in order to cut down irritation from insect pests. During the fattening periods, the general contenment of the animal is better, and his rate of growth is stepped up so that yields of meat are increased.

Heating and Lighting

Another contribution made by the petroleum industry to the farm is natural and liquefied gases for heating and lighting. Oil and gas are used to heat water and generate steam for washing and sterilizing churns, pails, bottles, coolers, and other dairy equipment. In the farmhouse, oil and gas are used in the kitchen and for lighting, heating, and refrigeration. In spite of electrification programs, it is estimated that there are still 4,000,000 rural homes lighted by kerosine lamps. The use of oil for heating and lighting is still increasing even where wood is available. Petroleum products are used for flame weeding, tobacco curing, and hay drying.

In the poultry industry incubators and brooders are largely heated by gas burners, and most of the cowsheds are still heated and lighted by gas. Liquefied petroleum gases consisting of propane and butanes have many uses on the farm in supplying motive power, in smoking meat and ripening vegetables, in heating incubators and stock tanks, and in pasteurizing and sterilizing.

In citrus orchards each acre requires about 50 smudge pots. There are about 4,000,000 of these orchard heaters in the orange groves of California, and in a normal year each heater burns about one gallon of oil. However, in an emergency they burn much more. In 1937, during an "unusual" freeze, smudge pots were operated nightly for two weeks, and in one of these nights 20,000,000 gallons were burned to insure safety of the orange crop. While oil is the principal fuel, coke briquettes also are used. Recently developed equipment for keeping citrus trees warm during frost periods comprises a hot-air furnace with a rotating fan at the top for directing warm air at the trees.

Fertilizers

Petroleum provides source materials for fertilizers and soil fumigants. Ammonia is produced by interaction of hydrogen made from natural gas, and nitrogen obtained by the fractional distillation of liquid air. This ammonia is injected directly from cylinders into irrigation water used on garden truck crops and in orchards.

Ammonium sulfate fertilizer is made by reacting ammonia with sulfuric acid derived in turn from the sulfur present in petroleum and natural gas. The controlled application of sulfuric acid to alkaline soils encountered in many arid regions neutralizes them sufficiently so that crops can be grown under irrigation.

Nitroglycerin for the manufacture of dynamite is made from products of petroleum and products of the farm. Petroleum supplies nitric acid by the oxidation of ammonia, and this is reacted with glycerin from oils, fats, and petroleum. The uses of dynamite in forests and on farms are numerous.

Soil Fumigants

From ethane, the second constituent of natural gas (which consists principally of methane), 1,1-dichloro-1 nitroethane is produced. This compound is a fumigant for insect pests which attack stored grain, flour, and cereals. It can also be used with deadly effect against the insects which attack stored tobacco, grain, flour, cereals, and furs. Organisms harmful to crop growth are also destroyed by the use of another compound manufactured from hydrocarbons present in refinery gases. This compound is known commercially as D-D, and chemically as dichloro-propane-dichloropropylene. By the injection of this preparation below the surface of soils, bacteria harmful to crops are exterminated and the growth of crops thereby promoted.

A special use of DDT is the injection of a 5 percent kerosine solution into soils to kill termites.

Insecticides

The mighty battle between man and the insects continues unabated. The farmer, his crops, and his livestock are engaged in constant warfare with these flying, buzzing, crawling, biting, sucking, and boring forms of life, which cause terrific crop losses and much sickness and devitalization among poultry, pigs, sheep, and cattle. Some idea of the magnitude of the problem may be gained from the fact that there are 80,000 different kinds of insects in the United States. A single acre of a farmer's land may supply food on an average for 15,000,000 insect pests. These agricultural enemies are responsible for losses of more than $2,000,000,000 a year. In the field of insecticides and fungicides for reducing these losses, petroleum is an important contributor. About 75,000,000 gallons of petroleum fractions alone are used annually for insecticidal purposes. Specially refined petroleum fractions are used as solvents or vehicles for DDT, pyrethrum, and other insecticides.

The most widely heralded insecticide discovery in the last few years is DDT. This compound (whose chemical designation is p.p-dichloro-dipthenyltrichloroethane) was first synthesized in 1874, but remained a laboratory curiosity until a short time ago. During the course of experiments with different insecticides, this material was brought out of obscurity and tested as to its potency. The results were startling. Its death dealing properties eclipsed all previously tried compounds. During the war it was manufactured on a tonnage basis. The steps in its production involve the chlorination of ethyl alcohol to produce chloraldehyde, the chlorination of benzene to chlorbenzene, and the condensation of these products using fuming sulfuric acid as a condensing agent. The product obtained is a white powder soluble to the extent of about 5 percent in kerosine and other organic solvents. With the exception of chlorine, all of the necessary chemicals and reagents for the production of DDT can be obtained from petroleum. The alcohol may be made from the fermentation of grains or from ethylene found in cracked refinery gases. The benzene can be separated from cracked products or produced by the dehydrogenation of cyclohexane, and the sulfuric acid made from sulfur contained in various petroleum fractions.

DDT has been found to be lethal against many deadly insects which plague both men and animals, and which retard plant growth. It is probably the most potent single agent yet developed for killing the greatest number of species of insects. It will not kill all insects and must be used properly since it is toxic to cold blooded animals, such as frogs and fishes, and also to bees necessary for pollination of flowers and plants. It is practically non-toxic to human beings and warm-blooded animals, although it is not recommended for spraying grains, fruits, forage plants or other crops used as human or animal food.

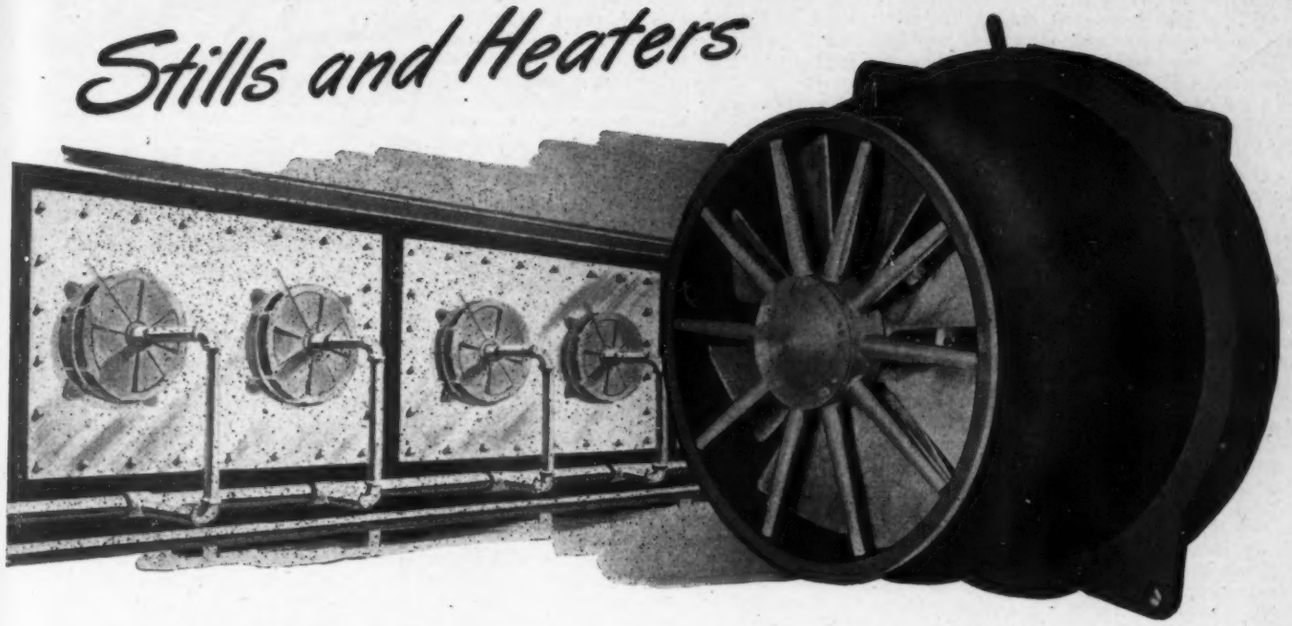
DDT is particularly effective in ridding localities of flies and mosquitos. When the walls of houses, sheds, and barns are sprayed with an oil solution or aqueous suspension of DDT, flies that contact the sprayed areas are killed by a sort of creeping paralysis which results in a dance of death. The walls require spraying only at intervals of two or three months. Such treatments have been particularly valuable in dairy farms where flies are kept from stables and milk houses. In a recently tried application cows were sprayed with 0.2 percent DDT suspension in water, every 12 to 16 days of the summer season until the fall frost. This treatment, which costs about $1.00 per cow per season, has resulted in an increase of 10 percent in milk production because of lack of irritation from flies and mosquitos. The milker is also spared the effect of the swishing cow's tail. A fly-controlling program is under way in the Middle West involving more than 10,000,000 dairy animals. Meat animals are more easily fattened when the DDT treatment is applied to kill insects.

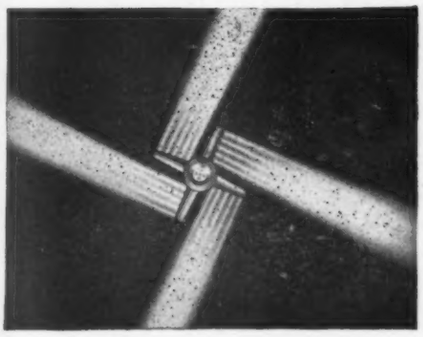
Several new compounds have been developed which are analogous to DDT in structure, but have fluorine in place of some of the chlorine atoms of the DDT molecule. In some tests on caged insects, DDT killed 90 to 95 percent, while fluorine-containing compounds killed all. In other cases the DDT was more effective, particularly against the common fruit fly.

Another recently developed insecticide which frequently equals or exceeds DDT in effectiveness is the gamma isomer of hexachlorocy-clohexane known

"BUNSEN'S DREAM" UPS THRU-PUT OF

Stills and Heaters





Bunsen, developer of the first gas burner, believed that "An ideal gas burner is one in which there would be an infinite number of gas orifices interposed across the air stream." And that is as close a description as you could get of the Coppus-Dennis FANMIX Burner.

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On New Installations, Fanmix Saves

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as Gammexane. This compound is directly producible by chlorinating either benzene or cyclohexane obtainable from petroleum products. The compound is in some cases more effective than DDT. It kills a wide range of insects, including mosquitos, grasshoppers, cockroaches, lice, and mites. Like DDT, it is soluble in kerosine and can be used in solution, in a water emulsion, or as a dust. It can also be used as a fumigant by vaporizing it.

There are a number of other new insecticides based on petroleum products. A recent patent covers the use of "a hydrocarbon oil of highly cyclic nature having a specific gravity of at least 1.0 based on water." This oil consists largely of high-boiling aromatic hydrocarbons which settle through pond water instead of remaining as a surface film, and more effectively kill mosquito larvae. Cresylic acids from petroleum may be added to the aromatic hydrocarbons to further increase the toxicity of the material.

Better Than DDT

Another insecticide manufactured from petroleum is a chlorinated hydrocarbon called Velsicol, which is used as an insecticidal spray or a paint ingredient. The first tests by entomologists have revealed that it is several times more effective than DDT, particularly against houseflies, potato beetle larvae, and cockroaches. It is apparently twice as poisonous as DDT to aphids. A further claim is made that this preparation is on a par with DDT in destroying wrigglers of the malaria-carrying mosquito. It killed adult grasshoppers more than five times as readily as DDT and was three times as toxic to adult cockroaches. In paint or residual sprays, the lasting power of this insecticide as indicated by its volatility is less than that of DDT, but more than that of the potent Gammexane.

A new repellent for mosquitos has been recently developed. This compound is 2-ethylhexane-diol-1,3, and is producable from petroleum hydrocarbons.

Another petroleum product, sodium naphthenate, is used in emulsified spray oils. This compound, because of its wetting action, tends to spread over a plant in an even and continuous film which covers and penetrates the hard shells of parasites.

The vapors of some hydrocarbons have a definite fungicidal action. In one series of tests young cabbage plants were completely protected against mildew disease by an atmosphere containing small amounts of the vapor of benzene. The plants were covered by a canopy of wet cloth, and wads of cotton soaked in benzene were suspended under the canopy three nights a week for a month. This prevented the mildew disease completely, but when the treatments were stopped, the mildrew became epidemic. A similar disease in tobacco seedlings was controlled by the same treatment with the vapors of benzene or dichlorobenzene.

The cold-flame oxidation of hydrocarbons is now being used to produce aldehydes which are water soluble and which have strong disinfectant properties. Both laboratory and field experiments have shown that the solutions can be substituted for Formalin in the fungicidal treatment of seed grain, and in combatting plant diseases.

Growth Regulators

The use of vapors of olefinic hydrocarbons as fruit ripeners is an important agricultural development. The gaseous olefins are ethylene, propylene, and butylenes. Ethylene is obtained either by the dehydration of alcohol from grain fermentation, or from cracked petroleum gases in which it occurs along with propylene and butylenes. It has been found that exposure to traces of ethylene gas speeds up the natural coloring of fruits by reacting with the green chlorophyll. This activity of olefin gases was discovered when the fumes from a kerosine stove were observed to be effective in bringing about the ripening of citrus fruits. The fumes from the stove contained only a trace of ethylene, but the ethylene was nonetheless the agent responsible for the ripening. Since the original observation, well-regulated experiments have shown that ethylene, propylene, and butylenes all have an effect on plant growth. Ethylene has no effect on the natural color which appears on ripe fruit. It speeds the conversion of starches and sugars, makes the product more palatable, and has no effect on vitamin content. Treatment with ethylene added more than $4,000,000 to the market value of Florida's citrus fruits in one year.

From 20 to 100 percent increase in the yield of potatoes has been noted when seed potatoes are treated with ethylene gas. The tuber grown from seed potatoes which had been exposed for 24 hours to atmospheres containing 7.5, 15, or 30 percent of gas at 18° C. were more numerous, larger, and richer in vitamin C. It is claimed that this process is cheaper than the application of hormones. Ethylene and propylene, besides stimulating potato growth, have been found to shorten the growth season for tomatoes, grapefruit, and oranges.

Researches with butaylene gas showed a stimulating effect on the maturing time of such trees as the walnut, peach, apple, cherry, plum, apricot, and pear. In periods when the season is too short to allow the full maturing, due to winter weather being so prolonged that flower formation and fruit setting are delayed, butylene may be used to shorten the growth period. Another method for ripening fruits is to use pentylenes, hexylenes, and heptylenes from cracked gasoline.

Ethylene gas has a variety of other uses in industry. By its controlled polymerization a plastic material known as Polythene is made which finds extensive use as cable insulation. In another process, ethylene is polymerized to make high-grade lubricating oils. It is also a necessary chemical in manufacturing tetraethyl lead.

Weed Killers

An interesting and important development is taking place in the field of weed killers for both grasses and field crops.

There are more than 100 new weed killers, among which 2,4-dichloro-phenoxyacetic acid is one of the most effective. This compound, called 2-4-D, has a highly selective action in killing weeds in grass plots, lawns and pastures, without damaging the grasses. Other weeds readily killed include chickweed, pigweed, wood-sorrel, knotweed and broadleaf dock. Quantities of the spray containing one tenth of 1 percent of 2-4-D selectively killed white clover, frequently considered undesirable in golf greens. Well established bluegrass was not injured. The creeping bent grasses were much less resistant but resistant enough to permit the killing of susceptible weeds without being destroyed themselves.

Stimulated by an overdose of the compound, the weeds commit suicide by growing so fast that their root systems enlarge, split, and disintegrate. Bindweed, a notorious western pest, which is normally a short-rooted plant, sends roots down to a depth of more than a foot under the urge of 2-4-D and then dies and fertilizes the soil.

Defoliants

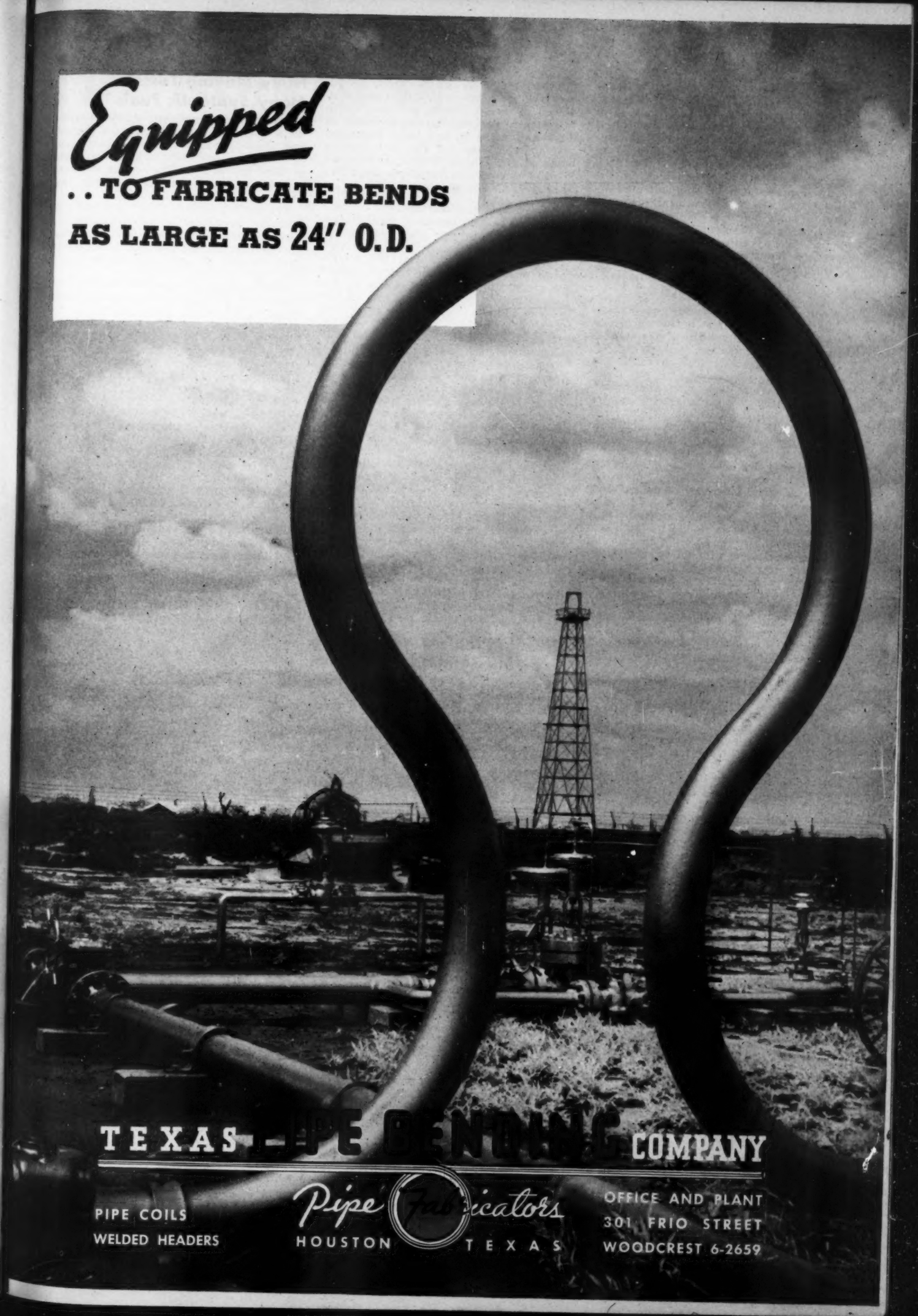
An important improvement in cotton picking is the use of defoliants such as sodium isopropylnaphthalene sulfonate, or sodium salts of sulfo succinic acids. By dusting cotton fields with such compounds from low-flying airplanes at picking time, the leaves are removed from the plants and picking is greatly facilitated.

Chemical Products

Every organic chemical known to man can be synthesized from some farm product at a price. The full import of this statement may be realized when the 500,000 known organic compounds are considered. One source of base products for chemical manufacture is the controlled fermentation of grains to make alcohols and ketones. During the war the fermentation processes played an important role in synthetic rubber through the production of alcohol. As late as July, 1943, 70 percent of the butadiene component for Buna-S synthetic rubber manufacture came from grain alcohol. One gallon of 95 percent alcohol produces 2.2 pounds of butadiene. Ethylene from alcohol was also used in the alkylation of benzene to produce styrene. The copolymerization of the 2.2 pounds of butadiene with stryene then produces 2.5 pounds of Buna-S rubber. With postwar demands being less imperative, all installations producing butadiene from alcohol have been shut down because of high cost compared to butadiene from petroleum.

During the war the Japanese used several ingenious methods for increasing their wasting supplies of aviation fuel by the use of farm products. In one method grains were fermented to produce butyl alcohol, these were dehydrated to butylenes, and then they were isomerized to isobutylene, which was polymerized to isooctenes and hydrogenated to isooctanes of 95 octane rating. The Japanese even went so far as to crack their excess supply of natural rubber to make motor fuel, and to distill terpenes from cypress tree roots for the same purpose. In China plants are operated for cracking tung oil to produce motor fuel, diesel fuel, and lubricants.

The use of alcohol as a component of motor fuels is an ever recurring question. The oil industry has frequently been criticized for its lack of enthusiasm for converting farm products into alcohol for motor fuel use. The use of alcohol in motor fuel is not economically feasible at the present time due to costs. If changed economics and needs indicate that alcohol should be used, the petroleum industry will not hesitate to use alcohol as motor fuel. At the present time over 50,000,000 gallons of ethyl alcohol are being produced yearly from petroleum products at a price level be-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low fermentation of grain. Even in countries where military or political rather than economic reasons have forced farm alcohol into use, it has been discovered that a more satisfactory and cheaper way to supplement oil supplies is to make oil from coal. When the need arises, our petroleum supplies in the United States can be supplemented by our ample reserves of natural gas, coal, and oil shale before alcohol will be competitive on a basis of our present-day knowledge. Technical processes are available but are not economic compared with petroleum.

Chemicals from Gas

Natural gas will play an even greater role in the production, not alone of motor fuel, but also chemical compounds such as ethyl alcohol, propyl alcohol, butyl alcohol, acetic acid, acetaldehyde, etc., through its conversion into water gas, i.e., carbon monoxide and hydrogen. A $20,000,000 plant is being erected in Texas to process 64,000,000 cu. ft. of natural gas daily. The products from this plant will be competitive with farm products.

A chemical called furfural, important to the oil industry, is derived from oat hulls. About 2.5 percent of an oat crop is convertible to oatmeal, which leaves a huge supply of oat hulls utilizable only as cattle feed or as fuel. At the present time furfural produced from this former waste product is utilized as a selective solvent in refining of lubricating distillates to manufacture finished lubricants.

The public is familiar with the great variety of products which are now manufactured from soybean oil. Lecithin recovered from this oil is used to stabilize color in petroleum products.

Food Preservation

Technical white oils are used in insecticide sprays, tree sprays and by bakers, fruit packers, and candle makers. Paraffin waxes have a multitude of uses, not alone on the farm but in home and the canning industry. They are used in thin films for preserving eggs, apples, and other fruits. Pasteurized eggs stored at room temperatures for six months are fresher than eggs in cold storage for the same length of time. A thermostabilizing process, using warm water and subsequent oil dip, has a pasteurizing effect against egg-spoiling organisms and also serves to devitalize the egg. Hydroxybiphenyl compounds are now available for preserving fruit from decay by counteracting the effect of bacteria. Windows of waxed paper in chicken houses admit more ultra-violet light than glass, and consequently improve the health of flocks.

Copper and zinc naphthenates are used successfully in protecting wood from the attacks of insects, fungi, and algae. A solution of either of these compounds in a petroleum solvent is more effective than the great majority of commercial preservatives on today's market. Copper naphthenate is also used to prevent the growth of fungus and mildew in cloth and canvas exposed to tropical temperatures and humidities. Thus it was used by the Army in soldiers' clothing and in their tents and truck covers. Without this preservative, material deteriorated in a month or so to an unusuable condition.

During the war a rat killer known as Number 1080, consisting of sodium fluoroacetate was developed. Weak aqueous solutions of this compound placed in infested areas are sure death to rodents, although no harm comes to dogs and cats. It has been estimated that there is one rat for each human being in the United States. The losses in food due to the voracious appetites of these animals are enormous.

Germ Warfare

Our chemical warfare service has been researching on new weapons of warfare far more deadly than the atomic bomb. Germs are sprayed from high flying planes which can destroy entire grain crops, even to the seeds in the ground, and wipe out all forms of life in large cities. The germs are of several types, and highly contagious. Fortunately, the United States is the sole possessor of the secrets involved in this new and devastating method of waging war by wiping out food supplies and infecting armies and populated areas.

The Southwest part of our country is one of the richest areas of the world and from the standpoint particularly of petroleum, natural gas, food, and industry. Its past and present achievements, great as they are, are but an index to a far greater future based on its natural resources, climate, and people. Many new industries are already functioning and many more are in the making. One of the new great projects involves a $20,000,000 plant to process 64,000,0000 cubic feet of natural gas per day to produce a host of useful products for world markets. One can view the future of the Southwest with high confidence in playing an ever increasing role in the economy of our nation.

Diesel Manufacturers See Growing Demand for Engines

Demand for diesel engines in the immediate future will far exceed the demand felt before the war, according to a statement made June 25 by Harvey T. Hill, executive director of the Diesel Engine Manufacturers Association. He addressed 39 college and university instructors in mechanical engineering assembled for a summer course at Pennsylvania State College.

Hill said today's engines are better than those built before the war. Where diesel engines 20 years ago were used almost exclusively for stationary and marine purposes, they are being built today for practically every type of application that calls for constant power. The government purchased a great number of diesel engines to be used in the war effort, then assigned thousands of service men to operate them—men who have returned to the business world well informed as to the diesel's operating efficiency and economy.

The coal strike, Hill said, created a demand for millions of dollars worth of diesel engines, for driving generator sets of all sizes. "Many power users have told me," he said, "that a coal strike will never catch them off balance again, because they are going to install their own diesel generating plant. Some plants are being put in as "standbys,' but many others will produce power that has heretofore been furnished by coal."

Hill pointed out further in his address, titled "Applications and Economics of the Diesel Engine," that during the coal strike, railroads whose locomotive equipment was dominantly diesel were able to maintain full service.

Navy Making Tests of Many Synthetic Fuels

Plans for a long-term study of synthetic fuels in co-operation with the oil and engine industries were announced by the Navy, following a demonstration of their use in standard watercraft and vehicles at the Naval Engineering Experiment Station at Annapolis.

Synthetic gasoline, diesel fuel and lubricants produced from natural gas, coal and shale were put into the tanks of boats and vehicles, whose performance showed no apparent change from that with natural products.

Navy studies of synthetic fuels were started in 1944. Laboratory studies indicated a high-cetane diesel fuel could be developed from natural gas, and that by blending with low-quality natural fuels the quality of the latter could be increased to meet Navy specifications, but the wartime shortage was solved before it became necessary to start large-scale production.

A sub-committee composed of petroleum refiners and engine manufacturers is working with the Navy in attempting to determine the properties of synthetic fuels and lubricants.

Scientists of the Esso Laboratories demonstrated progress that has been made in developing synthetic gasoline and diesel fuel.

The Navy's Bureau of Ships notified the Esso Laboratories early in May of its desire to stage the demonstrations and asked for several barrels of the synthetic gasoline and diesel fuel, meeting Navy specifications. To meet these requests, Esso Laboratories' scientists turned out these synthetic fuels at the large-scale pilot plant at Baton Rouge. Working with natural gas, the synthetic gasoline and synthetic diesel fuel were produced by the hydrocarbon synthesis process.

Other synthetic products tested at Annapolis included gasoline, diesel fuel and grease supplied by The Texas Company; gasoline and diesel fuel from shale by Union Oil Company of California, and diesel fuel from coal by Kuhlman Company of France.

Navy to Require 23 Million Barrels Fuel Oil For Year

Navy fuel requirements during the fiscal year beginning July 1 will include 23,492,779 barrels of fuel oil, 5,771,334 barrels of diesel oil, 179,970 barrels of motor gasoline, 98,448 barrels of aviation gasoline and 5480 barrels of kerosine, it was disclosed during hearings on the department appropriation bill.

Testimony before the committee disclosed that for the current year the consumption will include slightly more than 90 million barrels of fuel oil.

The Navy buys little fuel oil on the East Coast, getting it mostly in the Gulf and Aruba and moving it itself, transporting it to the East Coast at a cost of something under 40 cents a barrel, department officials testified. Supplies procured in the Persian Gulf are purchased from Arabian-American Oil Company and Bahrein Petroleum Company and some purchases also are being made from Anglo-Iranian Oil Company. The price there, it was said, is $1.05 per barrel, as compared with 95 cents a barrel at Aruba. It was disclosed that the department is paying considerable attention to new fuels, particularly for use in rocket-propulsion.

THE MONTH IN THE INDUSTRY

END of federal government price control with termination of the Office of Price Administration on June 30 loosed wild waves of rumor and speculation that receded but slowly as the Congress proceeded with consideration of new legislation to replace it. End of OPA came with a veto which was accompanied by a radio address which precipitated a campaign of name-calling in and out of the government which reduced statesmanship probably to its all-time low. News agencies, swamped with too much story and handicapped by their current penchant for interpreting rather than reporting the news, further confused the public by overplaying rent increases and isolated price advances, so that the only fact clearly to be discerned is that the clamor for reestablishment of price controls is a plea of the "little people" for protection from each other. For once, the landlord fears the butcher and the butcher fears the landlord more than either fears the "great monopolies." Labor leaders and their counterparts in the government who have been directing the regimentation predict disaster unless price controls are reestablished, and labor threatens more strikes.

Congress is debating a new price law, and the Senate already has eliminated oil and a number of other basic commodities from price controls. President Truman's position in the first veto probably will force similar action on any law coming out of the current action—and OPA will end.

The oil industry, clamoring for and hopeful of emancipation from price control up to the end of all controls, was cautious in entering its new freedom. Those among its spokesmen who publicly ventured opinion acted as if they thought the shortstop was hiding the ball. Price advances were considered pending by the sellers of crude oil, but buyers were hesitant, and no immediate advance was announced. William R. Boyd, Jr., president of API, summed up the situation in his statement that "prices of gasoline and oil products have always been determined by costs, by free competition." He spoke in the general language of the leaders of most big manufacturing and distributing industries. Meanwhile, the oil industry continues its operations only a few points below the record peak volume of the war period. This volume is producing satisfactory profit for the industry as a whole, notable exceptions being among the operators of "stripper" wells, whose predicament has been further complicated by elimination of subsidy payments which went out with OPA.

The amendment exempting gasoline, oil and all other petroleum products from revived price ceilings was sponsored by Senator E. H. Moore of Oklahoma. It forbids the imposition of price controls unless a decontrol board to be set up under the bill finds the supply insufficient to meet the domestic demand. Moore and other senators from oil-producing states said there is no reason to reinstate controls over gasoline and other products because the supply exceeds all demands.

The oil industry, just as it has been for the past several years, continues "waiting on action" in Washington before doing anything about boosting the price of crude oil and products.

Without a doubt there will be price increases eventually in crude oil and petroleum products. Nevertheless, in no instance has a company taken the position that there should be immediate price increases, although all said that price advances in both crude and refined oils were long over due because of heavily increased costs of producing and refining.

Costs Have Increased

"Oil is one of the few commodities which is selling at practically the same price it was selling at in prewar days," one company executive said. "It is well known that drilling and producing costs have increased substantially. The same thing applies to our costs of refining.

"There have been material wage advances and no corresponding price advances, but insofar as our company is concerned we have no disposition to take advantage of the situation existing in Washington at this time and even if OPA should be permanently removed from our governmental processes, it would be our disposition to proceed in a conservative manner, basing such increases as may come in the future on the additional costs we are experiencing," he said.

Increases Inevitable

Another executive said that nothing will be done about revising crude prices upward as long as there is a possibility of OPA being reinstated. It was this executive's opinion that even with OPA out of the way, major buyers will not rush forward immediately with a price increase for fear of public reaction.

He stated that major buyers can take the heckling by independent producers when price increases are delayed much better than they can withstand radio and newspaper razzing for jumping the price immediately after the demise of OPA.

This executive said he is reasonably certain that price increases are inevitable but believed that the increases will be in the form of a series of small raises instead of a big lump in order that gasoline prices may be altered proportionately."

Oil executives in California predicted price increases for some crudes but not an overall boost. They pointed out that heavy crude in California has been given a substantial rise since prewar days and that in some California fields 14- and 24-gravity crudes were selling for the same price, which should be corrected.

Some executives were inclined to believe that the retail price of gasoline

Conventions

August

8-10—Interstate Oil Compact Commission, Grand Rapids, Michigan.

25-28—American Institute of Chemical Engineers, Western Section, San Francisco.

September

9-13—American Chemical Society, Chicago.

16-20—National Instrumentation Conference and Exhibit, Wm. Penn Hotel, Pittsburgh.

18-20—National Petroleum Association, Hotel Traymore, Atlantic City.

October

3-5—American Institute of Mining and Metallurgical Engineers, Petroleum Division, Galveston, Texas.

7-12—American Gas Association, Atlantic City.

November

7-8—Society of Automotive Engineers, Fuels and Lubricants Meeting, Tulsa.

11-14—American Petroleum Institute, annual meeting, Stevens Hotel, Chicago.

Boyd Sees No Change Because of OPA End

"The prices of petroleum products have always depended upon the costs of production and the ceaseless competition between oil companies rather than upon OPA edict," said William R. Boyd, Jr., president of the American Petroleum Institute, in commenting upon the removal of arbitary price controls.

"The past performance of the American petroleum industry in raising the quality and reducing the price of its products is the best assurance the public can have that those services will continue," Boyd added.

"Prices of gasoline and oil products have always been determined by costs, by free competition among hundreds of active and efficient oil companies. Like most typical American business, the oil industry is aggressive and competitive both as to product price and quality. This basic fact is not changed by the ending of OPA. Prices of petroleum products, whether gasoline, motor oils or the multitude of fine products manufactured by the industry, will not be changed because of the ending of OPA. The petroleum industry, like other sound American industries, will do its best to hold the line on product prices. The industry believes that more production, more efficient distribution, and better products, hold the key to American prosperity.

"Under normal conditions costs vary and prices vary with costs. If we all work together, in due course not only can product prices be held but in many cases they can be reduced as full production and efficient operation are achieved by the effective cooperation of companies, employes and the public."

THE MONTH...

could go up 2 cents a gallon without public resistance.

Although most executives would not express themselves on the exact amount of the expected increase, some did mention 25 cents per barrel on crude and one cent a gallon on the retail price of gasoline as the maximum.

One large independent purchaser of crude oil said the oil industry "has better sense than to kick itself in the teeth" by increasing prices now.

"Why speculate?" said a company executive. 'We will follow the leader."

Federal Oil Revenues Show Considerable Drop

Treasury revenue from the taxes on lubricating oil, gasoline and pipe line transportation for the fiscal year ended June 30 will be $20,000,000 or more below the total for the preceding fiscal year, the Internal Revenue Bureau has indicated.

For the first eleven months of the year lubricating-oil collections were $68,362,624, a $10,965,683 drop from the same period the year before; gasoline receipts were $366,657,278, a drop of $3,878,829 and pipe line movement paid $13,741,754, a drop of $1,238,955.

For the first five months of 1946, $24,862,741 was collected from lubricating oil, a drop of $15,000,000 from last year; $144,630,688 from gasoline, a drop of nearly $23,000,000, and $6,042,044 from pipe line transportation, a drop of $630,000.

For May alone the collections included $4,659,536 from lubricating oil against $9,924,124 last year; $29,061,094 from gasoline against $42,631,374, and $1,228,920 from pipe lines against $1,585,845.

Bureau of Mines Reports Demand Increase Steady

A July demand for 4,748,000 barrels of domestic crude oil daily was forecast by Bureau of Mines as officials prepared to revise the long-range forecast issued last month for the final half of the year, in recognition of a continued demand materially in excess of anticipations.

The July average is 74,000 barrels daily above that for June, and it is expected that third-quarter demand will continue at that level or better. Bureau records show that demand has been increasing steadily, the actual in March being 4,608,000 barrels daily and the indicated for April increasing to 4,670,000 barrels and for May to 4,790,000 barrels, a rate which is believed to have continued through June.

"The latest current data available indicates that demand for domestic crude petroleum in the second quarter of 1946 may approximate 4.75 million barrels daily, about 2 percent greater than was originally forecast," the bureau commented. "From present indications, demand may continue at about this rate during the third quarter unless an excessive increase in stocks of refined oils should occur."

Gasoline Stocks Reduced

The yield of gasoline from crude, 37.8 percent in the first quarter, is estimated at 38.8 percent for the second quarter, but stocks of finished gasoline increased only 5.8 million barrels during the first three months and may have been reduced by as much as 12 million barrels in the second quarter. Total demand for motor fuel was 171.4 million barrels in the first quarter and may be about 202 million barrels for the succeeding three months. Exports in the second quarter, however, are believed to have been substantially lower than anticipated.

Crude runs to stills averaged 4,609,000 barrels daily in the first quarter and are estimated at 4,760,000 barrels daily for the second quarter. With the maintenance of relatively low gasoline yields, it was pointed out, the increase in runs has resulted primarily in a larger production of fuel oils than was anticipated.

Despite the heavy activity, operations are not resulting in the buildup of excessive stocks of refined products, bureau officials said. This is particularly true of residual fuel, which is still tight, and there has been heavy buying of light oils in advance by distributors and consumers, apparently in anticipation of price increases in the near future.

Bureau of Mines Reports Oil Statistics for 1944

United States crude petroleum production in 1944 reached a total of 1,677,904,000 barrels, with an average value of $1.21 per barrel at the well, an increase of 172,291,000 barrels and one cent per barrel in price over 1943, the Bureau of Mines has reported.

Crude runs to stills reached a new high of 1,665,684,000 barrels, an increase of 235,900,000 barrels over 1944, with refinery operations reaching their peak in December when they averaged 4,681,000 barrels daily.

Motor fuel production totaled 739,340,000 barrels for the year, a gain of 131,200,000 barrels, while distillate fuel oil amounted to 239,152,000 barrels, an increase of 27,600,000 barrels. Residual fuel oil production was 461,455,000 barrels, an increase of 44,000,000 barrels; kerosine, 78,344,000 barrels, an increase of 6,100,000 barrels, and lubricating oil, 41,106,000 barrels, an increase of 2,500,000 barrels.

Total domestic demand, including military demand at home and abroad, was 1,780,350,000 barrels against 1,595,729,000 barrels in 1943.

Crude imports were 44,800,000 barrels in 1944 against 13,800,000 barrels the preceding year, while crude exports were 34,200,000 barrels against 41,300,000 barrels.

The total number of producing wells increased from 407,170 at the end of 1943 to 412,220 at the close of 1944, and the average production per well increased from 10.2 to 11.2 barrels per day.

British Public Asking For Additional Gasoline

Efforts to force the government into releasing more motor fuel for normal public consumption have been intensified in Britain. The argument advanced by those pressing for more fuel—mainly the opposition in the Commons—is that the limitation of petroleum allocations to the civilian is limiting every aspect of national life. The opposition cites that more petroleum would quicken the tempo of public life. The government's argument against releasing extra supplies of gasoline is largely the same, that such an action would lead to a quickened tempo, but to one which the nation cannot at present afford.

The extra gasoline, the government points out, would be used for pleasure motoring, or for enterprises and activities not vitally essential in national life.

The motor industry and other interests anxious to obtain added allocations of petroleum are pointing to the fact that Continental countries offer unlimited gasoline and more and more British people are going abroad to enjoy the motoring. Thus, they are spending sterling abroad which could be spent to better purpose at home.

Lead Supply Continues Tight Despite Imports

The lead situation continues tight despite plans for increased imports. Domestic production is currently running at a rate of 350,000 tons for the year, compared with 387,000 tons actually produced in 1945, CPA has reported. July demands presented by lead consumers called for 70,000 tons, but it is believed that some of these requirements were excessive.

To maintain an even flow of the metal to consumers, 6000 tons will be "borrowed" from the government stock, now

Trends of Operations and Changes in Stocks

Figures on crude stocks are from Bureau of Mines weekly reports; all others from American Petroleum Institute weekly reports, which are estimates on Bureau of Mines basis.

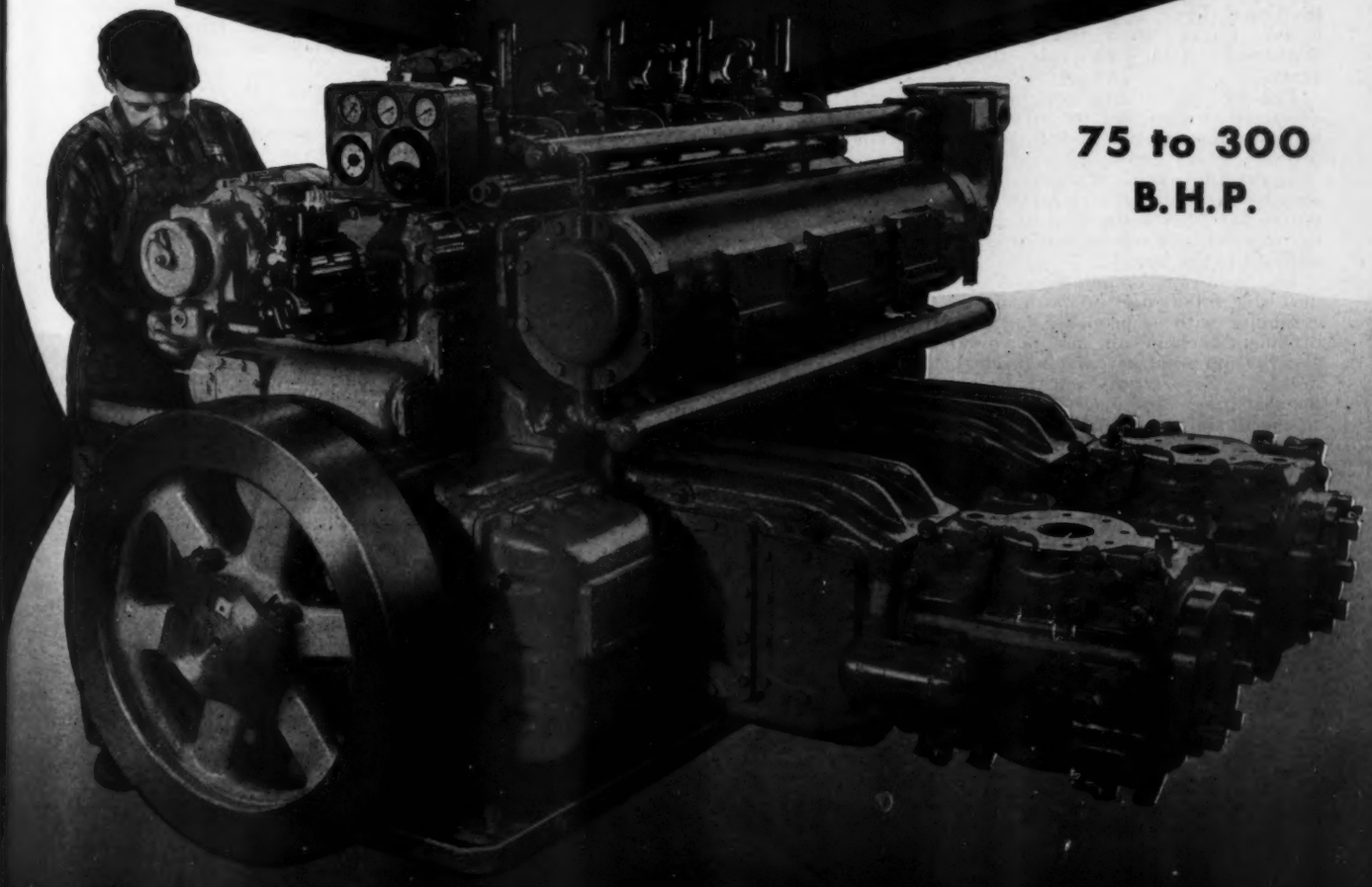
(All figures in thousands of barrels—add 000)

Trends in Week Ended:	Crude Oil			Gasoline		Gasoil and Distillate		Residual Fuel	
	Production Daily	Runs to Stills Daily	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End
1945:									
January 27	4,727	4,756	221,310	14,957	88,223	4,843	33,561	9,252	51,119
February 24	4,777	4,803	219,351	15,500	95,972	4,958	28,753	9,084	46,713
March 31	4,781	4,677	223,782	14,644	98,758	4,548	26,889	9,184	41,745
April 28	4,805	4,780	223,474	14,633	94,068	4,636	28,273	9,379	39,813
May 26	4,887	4,950	222,831	15,194	89,121	4,667	29,184	9,670	38,548
June 30	4,903	4,999	220,781	15,546	86,472	4,910	32,213	9,077	40,488
July 28	4,930	4,996	218,507	16,106	86,008	4,598	36,071	9,586	42,283
August 25	4,892	4,931	211,813	15,986	84,693	4,960	39,782	9,356	46,201
September 29	4,357	3,812	222,387	11,913	79,552	3,940	43,689	7,047	46,853
October 27	4,273	4,838	224,230	15,530	74,335	5,159	43,472	8,691	45,043
November 24	4,469	4,648	219,363	15,681	83,184	4,802	45,258	8,800	47,474
December 29	4,474	4,729	218,918	14,546	95,205	5,055	36,651	8,765	42,447
1946:									
January 26	4,626	4,553	220,544	13,622	107,737	5,720	29,498	8,411	39,722
March 2	4,726	4,779	229,430	13,871	104,462	5,888	25,148	8,634	38,441
March 30	4,425	4,684	221,214	13,896	104,715	5,357	28,240	8,738	37,746
April 27	4,672	4,685	221,689	14,228	99,631	5,568	30,466	9,204	39,404
May 25	4,759	4,857	222,214	14,322	95,769	5,463	32,973	8,908	43,368
June 29	4,957	4,854	222,193*	14,500	92,333	5,408	37,762	8,828	46,447

* Bureau of Mines, June 22, 1946.

or install it permanently!

THE CLARK M·A MIDGET ANGLE



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ONE OF THE DRESSER INDUSTRIES

SETS THE PACE IN COMPRESSOR PROGRESS

THE MONTH . . .

estimated at around 38,000 tons compared with 100,000 tons at the beginning of the year, to be replaced from imports later in the month.

For July, it is expected 4000 tons will be allocated for tetraethyl lead production, 160 tons under the 4160 tons provided in June.

API Directors Plan Activity Expansion

An expansion program, including broader membership, was adopted by the board of directors of the American Petroleum Institute meeting at Dallas, June 25-26. The session, which had been planned for Fort Worth and postponed because of the rail strike, was in lieu of the midyear membership meeting that was custom before the war.

The expansion program calls for increasing the number of production-division chapters from 14 to 20, continuation of the public-opinion survey, and widening of the institute's program of agricultural research. The directors voted to invite presidents of 20 oil-trade associations to become ex-officio members of the board. They further voted to amend by-laws to prevent any future vice president from holding office more than two years.

The API agricultural program, it was explained is designed to stimulate and originate research which will aid in solving agricultural problems.

Chairman George Krieger of the institute's agricultural development committee has been authorized to carry out the research and educational program he outlined to the board.

The program contemplates research into the fuller use of farm products, combined with oil products, in the fields of plastics, chemicals and new materials; the potential use of oil products in increasing soil fertility and the improvement of fungicides, insecticides and crop ripeners; and the better utilization of oil products in power farming.

Krieger said he had a number of research projects in mind and expected to have the program well under way within a matter of months.

In approving the continuance of the public-opinion survey, the directors cited that the public relations will be among the foremost subjects at the annual meeting in Chicago, November 11-15. At that time public relations specialists will be heard. One day of the annual meeting will be devoted to the subject.

The next meeting of the directors will be held in Washington, D. C., at a date to be named by Wm. R. Boyd, Jr., president.

Monsanto Awards Provide Advanced Scientific Study

Monsanto Chemical Company has named four industrial scientists who will be awarded leaves of absence at full salary for an academic year of study at universities of their choice.

Announcement of the awards inaugurated a program, a new move in American industry, to enable scientists to renew their studies and to establish close cooperation between industry and the university laboratory.

Named to receive the awards were Louis P. Wenzell, Jr., St. Louis, Missouri; Colver P. Dyer, Winchester, Massachusetts; Carlyle John Stehman, Dayton, Ohio, and Eli Perry, Springfield, Massachusetts.

A former student at Princeton and Washington Universities, Wenzell is a plant investigation group leader in the Monsanto plant in East St. Louis. Dyer is a graduate of Massachusetts Institute of Technology and is a group research leader at the Merrimac division plant in Everett, Massachusetts. Stehman received degrees from the University of Illinois and Pennsylvania State College and now is a group leader in the Monsanto Central Research Department in Dayton. Perry is a graduate of University of Pennsylvania and is a research engineer in the Monsanto plastics division plant at Springfield.

The awards were made by the company's executive committee in the basis of especially meritorious and outstanding scientific work while with the company, it was said. The program is applicable to all Monsanto scientific workers in the United States for attendance at universities within the United States. An unspecified number of awards will be made by the committee each year.

Socony-Vacuum Announces Research Discoveries

Development of three new chemicals and six important research discoveries were announced by Socony-Vacuum Oil Company at a "Petroleum Preview" conference in New York, July 2. The new chemicals are a trio of thiophene derivatives from petroleum, known as 2-methylthiophene, 3-methylthiophene and 2-acetylthiophene. The new derivatives are expected to assist in the development of drugs of increased therapeutic activity, and will find application in the chemical industry.

One of the research discoveries announced is a petroleum carrier for DDT, synthetic in nature and capable of dissolving up to 55 percent of its own weight of DDT. Control of mosquito larvae in swampy areas can now be obtained, it is said, by spraying as little as one tenth to one fourth of a pound of DDT per acre of surface area.

The company announced two contributions to the field of fuel oil heating; one a modification of the pot-type burner to allow this type burner to handle satisfactorily a 100 percent catalytically cracked distillate fuel oil instead of being limited to premium oils. The second is a "combustion test kit" which enables a domestic burner to be adjusted easily for maximum performance.

Still another Socony-Vacuum research product is S/V Sovabead, an improved dessicant in the shape of spherical beads of uniform size. Each bead is honeycombed with microscopic pores which draw moisture from the air. It can be used in air-conditioning systems to supplement refrigeration and has wide application as an anti-corrosive.

Standard of California Will Build New Unit at El Segundo

Standard Oil Company of California has announced plans for construction of a 30,000-barrel-daily crude distillation unit at its El Segundo refinery. Construction is scheduled to begin in September, with completion set for early next year.

Government Offers Reports On German Rubber Methods

Data on German synthetic-rubber production, including an account of German wartime research and descriptions of manufacturing methods, has been made available by the Department of Commerce publication board in a series of nine reports prepared for the Rubber Reserve Company by investigators of the Technical Industrial Intelligence Branch.

The reports cover a wide field of subjects, including descriptions of production processes for Buna S-3, styrene and intermediate products used at the I. G. Farben plant at Huels, the second largest synthetic-rubber plant in Germany; data on the quality and characteristics of synthetic rubbers and compounding materials, and reviews of the progress of the German synthetic-rubber program.

A list of the reports, showing the prices at which they can be purchased, may be obtained from the Office of the Publication Board.

Freon Found Effective to Extinguish Gasoline Fires

The Bureau of Mines has reported that Freon 11 (trichloromono-fluoromethane) can be used effectively to extinguish gasoline fires and prevent explosions.

Freon 11 was one of six inert gases studied with a view to their value as gasoline-fire extinguishers and proved to be the best of the flame-quenching agents.

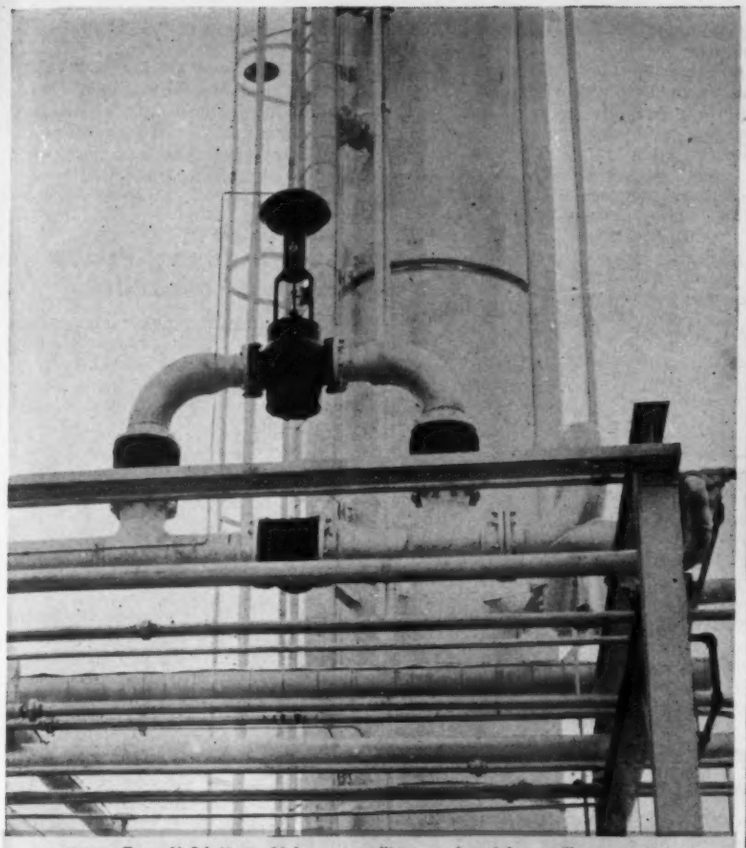
The apparatus used, methods of conducting the tests and the results obtained with the various inert gases in connection with gasoline vapor-air mixtures are described in Report of Investigation 3871 in graphic form which permits a determination of the explosion hazards of any given combination of the gases without resort to laborious calculations. Copies of the report may be secured without charge from the Bureau of Mines in Washington.

Mass Spectrometer Used in High-Vacuum Leak Testing

A specially designed mass spectrometer, that reveals gas leakages so minute that they defied conventional detection methods, was described in detail by two General Electric Company's research engineers at the recent American Institute of Electrical Engineers convention in Detroit. According to the authors, W. G. Worcester and E. G. Doughty, both of the company's general engineering and consulting laboratory, the specially developed leak detector can disclose the presence of one part of helium in 200,000 parts of air.

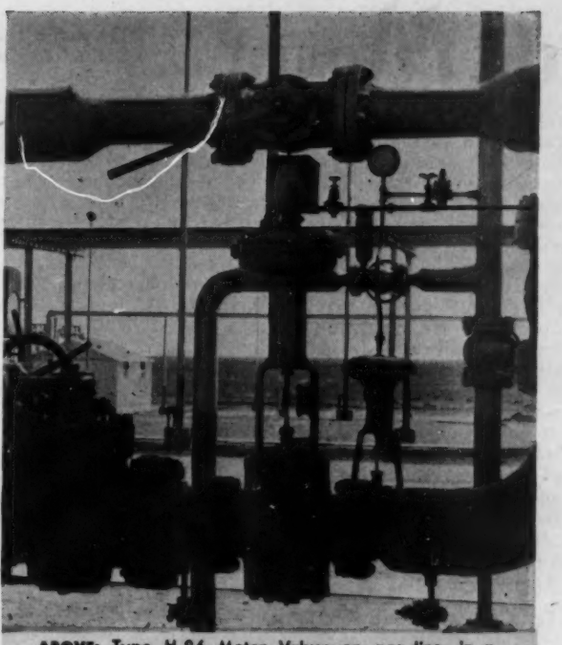
They said that the leak detector is a small portable mass spectrometer, a device which utilizes electric and magnetic fields to sort out ionized gas molecules according to their molecular weight. The instrument continuously draws a sample of gas from the system being leak tested, and indicates the partial pressure of helium in the sample. As portions of the test system are exposed to a helium jet, any helium entering the system through a leak causes an increase in the output current of the amplifier, thus indicating the prescence of the leak.

The leak detector may be used to

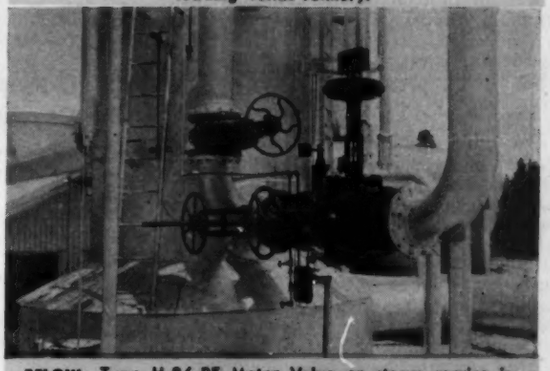


ABOVE: Type H-86 Motor Valves controlling overhead from still at prominent oil company's plant.

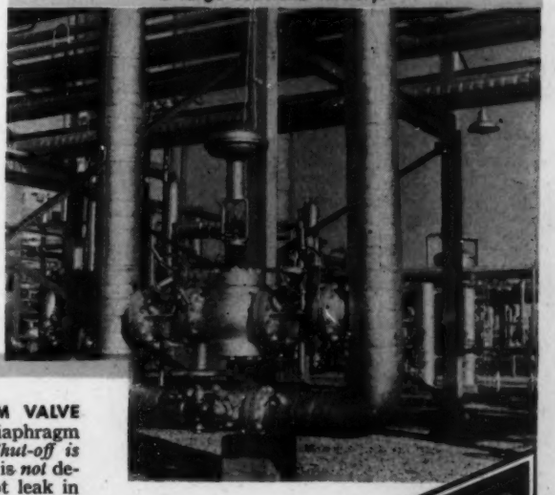
AT RIGHT: Type H-86 Motor Valve controlling pressure on Scrubber.



ABOVE: Type H-86 Motor Valves on gas line, in a leading Texas refinery.



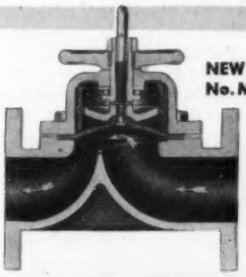
BELOW: Type H-86-RF Motor Valve on steam service in a large Louisiana refinery.



Where Production and Product Quality Depend On Dependable Controls

THROUGHOUT the oil industry McAlear Type H-86 Diaphragm Motor Valves are used in conjunction with instruments to control flow, temperature, pressure and liquid level—to handle air, gas, vapor, steam or liquid. Their "high lift" and "characterized" plugs give wide rangeability and constant proportional flow increase as valve opening increases with travel. For complete data on Type H Motor Valves, write for Bulletin No. 105.

BRING YOUR CONTROL PROBLEMS to McAlear. Draw on the wide experience of McAlear engineers... on their readiness and willingness to help you. For informative bulletins and catalog, write McAlear Manufacturing Company, Automatic Control Division of Climax Industries, 1943 South Western Avenue, Chicago 8, Illinois.



NEW ABRASIVE AND CORROSION PROOF DIAPHRAGM VALVE No. M-1455—Mechanism of this valve cannot jam because diaphragm separates it completely from liquids handled. *Shut-off is positive* even with solids trapped on seat. Closure is *not* dependent on metal-to-metal contact. Valve cannot leak in any position, requires no re-packing, no re-seating. Diaphragm is replaceable without removing valve from line. Special pressure operated Type M-1460 available for automatic or pilot control.

TYPE H-850 DISPLACEMENT TYPE LEVEL CONTROL—Friction-Free . . . Leak Proof . . . Exacting. For liquids of any gravity, temperature or working pressure, from minimum variations to maximum "wide range" variations of 120". Liquid specific gravity range from .05 to 2.0 with standard floats. Special floats for ranges exceeding 120". Especially suited to highly corrosive liquid service.

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THE MONTH . . .

reject defective parts, to accurately locate leaks so that the parts may be repaired, or as an aid in selecting production methods and in locating faulty processes, it was said. Results obtained by the leak detector are repetitive and the device can be used to measure rate of leakage by comparison with a calibrated leak. The sensitivity of a particular leak-test system may be obtained by observing the magnitude of the signal from a calibrated leak attached to the system.

The authors said that other applications of the leak detector are indicated in which helium may be used as a tracer gas. These include investigation of flow in ventilating systems, velocity and distribution of flow in piping systems, turbulence, and other similar problems.

Standard of Indiana To Close Two Plants

Wartime technological developments, it was announced by the company, have forced Standard Oil Company (Indiana) to a decision to close its refineries at Neodesha, Kansas, and Greybull, Wyoming, and consolidate their operations with those of other refineries, effective in 1948.

Catalytic cracking, the company explained, has developed a competitive situation that would require such equipment to be installed at these two refineries as well as at other company refineries not far from each of the two. Engineering studies showed, however, that this duplication would be uneconomic and compelled the decision to close the two plants.

Construction of catalytic crackers and related equipment has been decided upon for the company's Sugar Creek and Casper refineries. Negotiations will soon be opened with the unions at those plants to work out a basis for the transfer of Neodesha workers to such jobs as will be available at Sugar Creek and similarly for the transfer of Greybull personnel to Casper.

Workers not transferring when the shutdowns occur in 1948 yet remaining on the job in their present refineries as long as they are needed will be given a special service record allowance in relation to their length of service. Qualified men 60 or older and women 55 or older will be entitled, if they prefer, to receive retirement annuiites instead without waiting to reach the ages when retirement income would ordinarily commence under the company's annuity plan. To these people the company will also pay every month until they reach 65 a monthly rate approximately equal to the Social Security income they would begin to receive at that age.

Indiana Standard Plans New Offices at Whiting

Standard Oil Company (Indiana) has announced plans, to be executed when conditions will permit, for construction of a new office building at its Whiting refinery. The building will be of modern design and materials, and amply large to accommodate administrative offices, engineering and engineering research. It will be located close to the company's research center now under construction.

OGD Appropriation Cut By Conference Committee

The new Oil and Gas Division of the Interior Department will have a fund of $400,000 on which to operate during the next twelve months, instead of the $472,000 originally asked. The amount of the fund was fixed by the House as it passed on the work of the conferees on the Interior Department supply bill.

The Bureau of Mines will get $5,250,000 for its synthetic liquid fuel program; for oil and gas investigations the Bureau will get $826,750, and for helium investigations it will receive $100,000.

The OGD fund was asked after the bill had been passed by the House, and the Senate inserted an amendment giving it $449,516, which included $216,908 provided for operation of the Petroleum Conservation Division, now part of the new agency. The House conferees agreed to finance the division, but Representative Jed Johnson of Oklahoma, chairman of the appropriations subcommittee in charge of Interior funds and ranking House member on the conference committee, insisted that the amount be cut to $400,000.

Petroleum Industry Probe House Group Possibility

Possibilities that an investigation of monopoly initiated by the House Small Business Committee may extend into the marketing of petroleum have been raised by Chairman Wright Patman of Texas, who reported that marketing practices have been the subject of many complaints reaching his monopoly subcommittee.

"The growing tendency of large integrated manufacturers to extend their control clear through to the consumer," he described as a serious problem.

Patman also said that unless remedial steps are taken the peacetime benefits of the government expenditures on industrial research during the war will accrue to the large manufacturers who monopolize the prime contracts, and smaller manufacturers of technical products will be left far behind for lack of this data.

Similarly, he charged, WPB's premature dropping of wartime controls while serious shortages of materials and components still existed has worked to the disadvantage of small business.

Socony-Vacuum Enters Bottled Gas Field

Socony-Vacuum Oil Company has entered the liquefied petroleum gas manufacturing and marketing business, calling its product "Mobil-flame." The product is to be manufactured at the company's refineries in the East and distributed from supply points in New England, New York, New Jersey and Maryland. Dealer representatives, it was said, will be on an exclusive area basis, the dealers also distributing appliances.

Officers of the Pennsylvania Grade Crude Oil Association, elected in Pittsburgh, June 27 are shown above. From left to right: H. A. Logan, director, United Refining Company, Warren, Pa.; Fayette B. Dow, vice president and general counsel, Washington, D. C.; D. T. Ring, president and vice president of Preston Oil Company, Columbus, Ohio; Samuel Messer, treasurer, with Quaker State Oil Refining Corporation, Oil City, Pa.; W. F. Clinger, retiring president, Clinger Oil & Gas Company, Warren, Pa.; W. C. Wenzel, executive manager of the Association, Oil City. Officers not shown in the picture are B. T. Haskins, first vice president, Ebenezer Oil Company, Wellsville, N. Y.; G. J. Hanks, second vice president, and president of South Penn Oil Company, Bradford, Pa.; W. R. Reitz, assistant treasurer, Quaker State Oil Refining Corporation, Oil City; and C. L. Suhr, also assistant treasurer, The Pennzoil Company, Oil City.

Ring Heads Pennsylvania Grade Crude Oil Association

One hundred and thirty-five oil men attended the 22nd annual meeting of the Pennsylvania Grade Crude Oil Association at Pittsburgh, June 27-28.

D. T. Ring of Columbus, Ohio, was elected president of the association at a directors meeting which followed the membership gathering. Other officers named were B. T. Haskins, Ebenezer Oil Company, Wellsville, first vice president; G. J. Hanks, president, South Penn Oil Company, Bradford, second vice president; Samuel Messer, Quaker State Oil Refining Corporation, Oil City, treasurer; W. R. Reitz, Quaker State Oil Refining Corporation, Oil City, assistant treasurer; C. L. Suhr, The Pennzoil Company, Oil City, assistant treasurer; Fayette B. Dow, Washington, vice president and general counsel; and W. C. Wenzel, Oil City, executive manager.

Featured were addresses on various aspects of production and one by G. H. Sheldon, president of Sheldon, Quick & McElroy, Inc., of New York on "The Significance of Advertising to the Pennsylvania Grade Oil Industry," wherein the association was urged to continue its campaign which has been so success-

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THE MONTH . . .

ful in the past. "Advertising, like selling, is a job that is never finished and cannot be eased up; advertising is merely a means of selling to a market and a market is people," he said.

C. M. Gile Elected Gulf Vice President

Clement M. Gile has been elected vice president of Gulf Oil Corporation and Gulf Refining Company, and vice president and a director of Gulf Research & Development Company, succeeding W. V. Hartmann, retired. He will be in charge of marketing.

Gile entered the oil business with New England Oil Company in 1920, and became sales manager. He joined the Gulf Companies in January, 1926, as assistant to the general manager of sales. He was appointed general manager of refined oil sales in May, 1933. He has been vice president of Gulf Tire and Supply Company since it was organized. He is a graduate of Phillips-Andover Academy and Yale University. He joined the Navy in World War I; and after a short course at Annapolis, was commissioned an ensign, serving in the submarine service until the end of the war.

The Texas Company Shifts Three Plant Executives

Howard S. McCray, superintendent of The Texas Company's refinery at Amarillo, has been made superintendent of the company's plant at Lawrenceville, Illinois, S. W. Johnson, assistant superintendent at Galena Park (Houston), has been advanced to superintendent at Amarillo, and Leonard Lee, plant engineer, has moved up to assistant superintendent at Galena Park.

McCray received B. S. in civil engineering from Pennsylvania State College in 1926, and shortly after joined The Texas Company as an engineer at Port Arthur. After six years in engineering and construction he became assistant superintendent at Port Neches, and in 1940 was made superintendent at Sunburst, Montana.

H. S. McCRAY

S. W. JOHNSON

Johnson joined the company at Port Arthur in 1919, after brief teaching experience following graduation from Southwest Texas State Teachers College. He was assistant superintendent at Norfolk and at Lawrenceville before going to Galena Park in 1934.

Lee has been with the company since 1919 and at the Galena Park plant since August, 1945.

Winkler County, Texas, Gasoline Plant in Operation

C. V. Lyman, Midland, Texas, has placed in operation a 15-million-cubic-foot absorption type natural gasoline plant in the Emperor Deep field, Winkler County, West Texas. A portion of the residue gas will be used for repressuring while the remainder will be purchased by El Paso Natural Gas Company. The products have been contracted by Standard Oil Company of Texas for delivery to its El Paso plant through Pasotex Pipe Line Company's line.

Phillips Petroleum Company Enlarges West Texas Plant

Phillips Petroleum Company and associates have increased the capacity of their absorption-type of natural gasoline plant in the Fullerton field, West Texas, from 28 million to 40 million cubic feet daily. The plant has been enlarged twice since it began operating in March, 1945, and is processing sweet and semi-sour gas.

Plant Completed

Northern Natural Gas Company's new natural gasoline plant near Sublette, in Haskell County, Kansas, has been completed and is in operation. The plant is processing gas from the Hugoton field and recovering between 25,000 and 40,000 gallons of gasoline per day.

Western Petroleum Refiners Hold Meeting in Michigan

Waste disposal and water treating highlighted a regional technical meeting of Western Petroleum Refiners Association at Lansing, Michigan, June 20. This meeting was the first of a series to be held in the northern area, it was announced by John C. Day, executive secretary.

L. C. Burroughs, Shell Oil Company, Houston, covered the waste disposal subject (see page 81), while R. W. Kelly, Dearborn Chemical Company, Tulsa, discussed water treating problems.

American Chemical Society Planning Chicago Session

Dr. Fred C. Koch, director of biochemical research at Armour Laboratories, is general chairman of the 110th national meeting of American Chemical Society at Chicago on Sepembter 9 to 13. More than 8000 chemists, chemical engineers and representatives of allied fields are expected to participate in the sessions. All of the society's 18 professional divisions will convene, and several hundred papers will be presented.

H. D. Dale Made Manager For Shell at Wood River

H. D. Dale has been named manager of the Wood River refinery of Shell Oil Company, succeeding R. C. Roberts, retired. Dale started with the company at Wood River as a tank gauger in 1924, soon after graduation from the University of Pittsburgh. He progressed through various positions to head stillman, and in 1933 was named special technologist at the refinery. In 1940 and 1941 he assisted in correlating the design and engineering of an extension of the refinery, and in 1941 was made superintendent. He was transferred to New York in 1944 as manager of the operations department and advanced to assistant to the vice president of manufacturing. Recently he was on an inspection trip to Germany and Japan as

H. D. DALE

Photo courtesy Allis-Chalmers Mfg. Co.

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THE MONTH . . .

R. C. ROBERTS

a petroleum manufacturing expert with the Strategic Bombing Survey Mission. He visited most of the industrial plants in Western Europe and witnessed results of the atomic bombing in Japan.

Roberts started his career with Shell Oil Company in California in 1917 and moved to Wood River the following year. In 1928 he was made manager of the company's Arkansas City refinery, and since has been successively manager at East Chicago and Wood River.

Johnson General Manager For Haynesville Committee

H. B. Johnson has been selected as general manager for the Haynesville Operators Committee, to succeed J. R. Butler, who resigned recently to become vice president and general manager of Old Ocean Oil Company at Houston. Johnson has been general superintendent of operations of the Haynesville unitized field since 1944. A liquid hydrocarbon extraction plant is operated in connection with pressure maintenance in the field which includes 14,700 acres in Claiborne Parish, Louisiana, and Columbia County, Arkansas.

Seubert Ends Long Career With Indiana Standard

Edward G. Seubert, who reached his seventieth birthday on June 20, that day retired from Standard Oil Company (Indiana) after nearly 54 years service with the organization. Starting as a mechanics helper in the then newly built refinery at Whiting, at the age of 15, in six months he became a junior clerk, and from that time until he became a director of the company in 1919, advanced through the accounting and financial branch of the company's management. He was elected president, succeeding Dr. William M. Burton, in 1927, and became top executive officer upon retirement of R. W. Stewart in 1929, continuing as such until January 1, 1945, when he became chairman of the executive committee, the position he held at retirement.

Alther Opens Chicago Office as Consultant

Joseph G. Alther, formerly vice president and director of Universal Oil Products Company, has severed all connections with that company after thirty years of service. In May, 1945, his resignation was accepted by the board of directors who persuaded him to be available as consultant to them for a period of one year, which terminated May 31, 1946. Alther has established a consulting office in Chicago.

J. G. ALTHER

Sarasota, Florida, to Have Propane-Air Gas Plant

Southern Gas & Electric Corporation has awarded contract to Stacey Dresser Engineering, Cleveland, division of Stacey Brothers Gas Construction Company, Cincinnati, Ohio, for design and installation of a propane-air gas plant at Sarasota, Florida. The plant is designed to produce 550,000 standard cubic feet per day of 1000-Btu propane-air gas at 25 psig, and to operate at 5 to 100 percent capacity to meet seasonal conditions. Complete unloading and liquefied-propane storage facilities will include three 30,000-gallon tanks. The generating equipment will include a Btu recorder and controller.

Preparations Made for South American Parley

Central organizations of the South American Institute of Petroleum, meeting with national sections of the Institute in Argentina, Bolivia, Brazil, Chile, Ecuador, Peru and Uruguay, are making preparations for the First South American Congress of Petroleum which will convene in Lima, Peru, in March, 1947.

The central office of the Institute is answering numerous inquiries on the work and proceedings of the Congress, and is distributing the constitution and by-laws of the Congress throughout the Americas.

According to the constitution, official members will be the individuals and corporations already enrolled as active members. However, those expressing a particular interest in the Congress and its aims may be invited by the qualifications committee to become members.

The American Petroleum Institute of North America will send an official delegation to Lima to assist the members of SIAP in the preparatory work.

At a recent gathering at Tide Water Associated Oil Company's Avon, California, refinery, Herschel Y. Hyde (right), newly appointed vice president of manufacturing, was presented a pen and pencil set by members of the research and development department. Hyde, for many years head of the research department, received the gift from his co-workers in recognition of his cooperation and leadership. C. K. Viland, Hyde's successor as general supervisor of research and development, was master of ceremonies at the gathering and made the presentation.

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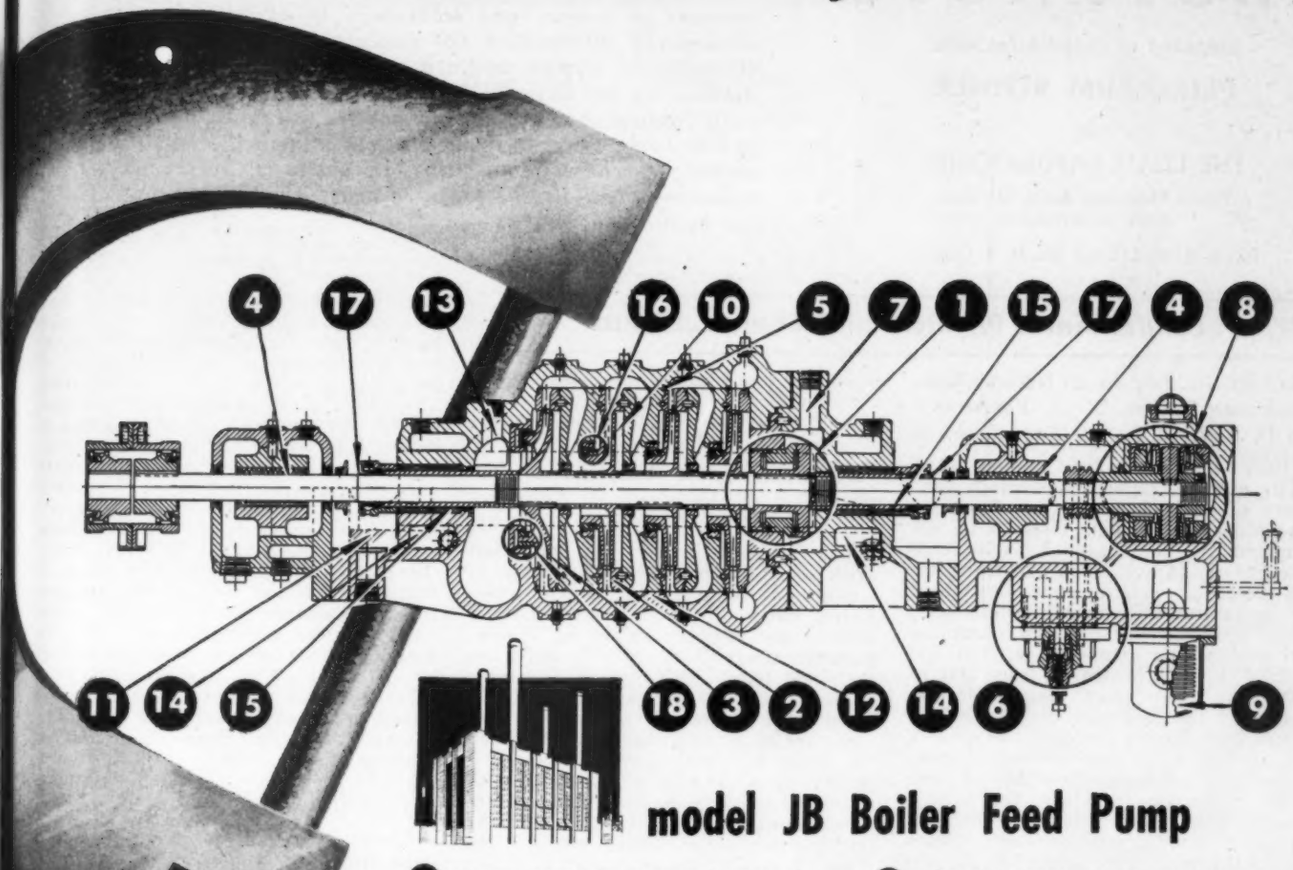

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under supervision of

DR. E. H. LESLIE and DR. H. B. COATS

The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by The Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

Carbon Dioxide in a Natural Gas-Condensate System. F. H. POETTMANN AND D. L. KATZ, *Ind. & Eng. Chem.* **38** (1946) pp. 530-34.

The authors report equilibrium constants of carbon dioxide in a natural gas-condensate system. These were determined over the range 1 to 10 mole percent of carbon dioxide. Densities and molecular weights were determined for the saturated vapor and liquid phases for 24 hydrocarbon solutions containing carbon dioxide at temperatures from 100 to 250° F. and pressures from 500 to 2900 psia. The lower the molecular weight of the hydrocarbon in the binary carbon dioxide systems, the greater the deviation of the carbon dioxide from ideal behavior. Equilibrium constants of carbon dioxide in the natural gas-condensate system deviate most from the ideal equilibrium constants. Since the multicomponent solutions contain over 60 mole percent methane, it is probable that the methane-carbon dioxide system will show wide deviations from an ideal solution. The apparatus and procedure used in the investigation are described in detail, and the results of the work are presented in six figures and four tables.

The Solubility of Acetylene in Acetone. V. E. BRAMELD AND M. T. CLARK, *Jour. Soc. Chem. Ind.* **65** (1946) pp. 58-61.

The authors review the published work on the solubility of acetylene in acetone and then describe a new gravimetric method for its determination. Results are presented covering a temperature range 0 to 40° C. under an acetylene partial pressure of 1 atmosphere. The data are calculated on a weight basis, since it is believed that these are of greater practical value than the more frequently given volume solubility data. The solubility coefficient is related to the temperature by an empirical equation which is valid over the temperature range —30 to +35° C. The equation is

$$Sw = \frac{13100}{T - 185.3} - 81.3$$

where T is the absolute temperature and Sw is expressed as milligrams of acetylene per gram of acetone. At pressures near atmospheric, the solubility of acetylene is directly proportional to the partial pressure of acetylene in the gas phase above the solution. The apparatus used in the work is described and the data are presented in tabular form.

Note on a Method of Estimating the Prandtl Number of Liquids. K. G. DENBIGH, *Jour. Soc. Chem. Ind.* **65** (1946) pp. 61-63.

One of the dimensionless quantities entering into the theory of heat transfer in fluids is the Prandtl number. This is defined by the equation

$$(Pr.) = \frac{c_p n}{k}$$

in which c_p is the specific heat at constant pressure, n is the viscosity, and k is the thermal conductivity of the fluid. According to the kinetic theory the modified Prandtl number $c_v n/k$ should be the same for all monatomic gases, and should have a numerical value of 0.4 which is independent of temperature. The true Prandtl number, $c_p n/k$, is also nearly constant, and for most gases is between 0.7 and 1.0. For liquids, however, the values of the Prandtl number vary over a wide range from 3 to over 10,000. Unfortunately, reliable experimental data on c_p, n and k are available for only a few liquids, and this limits the extent to which equations, such as that of Dittus and Boelter, can be used for the calculation of the film coefficient of heat transfer in liquids. The author has studied the possibility of relating the Prandtl number with some other physical property, the value of which is more generally known. The essential data for several solvents, including water, alcohol, glycol, hydrocarbons, chlorinated compounds, and a few others, are tabulated.

Construction of Nomographs with Hyperbolic Coordinates. W. H. BURROWS, *Ind. & Eng. Chem.* **38** (1946) pp. 472-77.

The author discusses the problem of the construction of nomographs, particularly the adjusting of the moduli and positions of the scales of a nomograph to increase accuracy and legibility. The subject is treated from the standpoint of the coordinate system rather than of the defining equation of the nomograph. A coordinate system is described such that variations in the value of a single factor, r, produce the desired variations in the positions and moduli of the scales. The general defining equation for nomographs is derived and shown to be independent of r. Thus the scale arrangements can be altered without changing the original equation of the nomograph. The mechanics of constructing nomographs based on this coordinate system and the method of selecting the desired value of r are illustrated by the construction of three different nomographs.

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The National Registry of Rare Chemicals, Armour Research Foundation, 33rd, Federal, and Dearborn Streets, Chicago 16, Illinois, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only one gram quantities, please inform the Registry.

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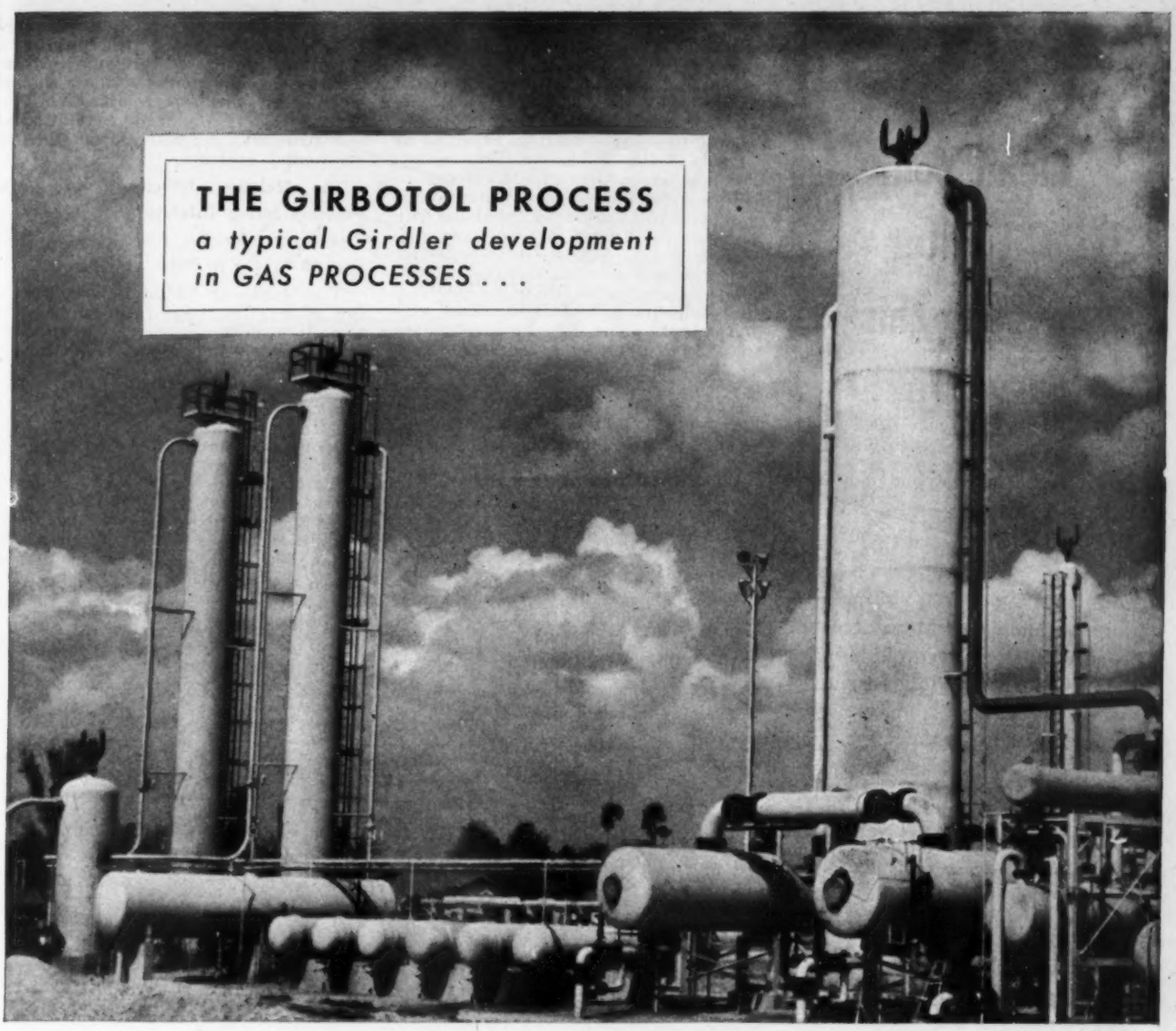
- o-Phenylene diacetic acid
- Cyclobutane
- Furfuryl mercaptan
- Isolinoleic acid
- Ethyl tetrasulfide
- 1,2-Naphthalene diisocyanate
- 2,4-Dinitrofluorobenzene
- o-Toluene sulfonyl chloride
- 3-Isopropyl phenol
- 3-n-Propylphenol
- 3-n, sec-, and tert-Butylphenol
- 2-Ethylphenol
- Cetyl stearyl sulfate

Chemical Compositions and Reactions

Alkylation of Paraffins in the Presence of Homogeneous Catalysts. A. A. O'KELLY AND A. N. SACHANEN, *Ind. & Eng. Chem.* **38** (1946) pp. 462-67.

The subject of alkylation of isoparaffins and paraffins with olefins is briefly reviewed. The authors then describe another method of alkylating paraffins in the presence of homogeneous catalysts such as aliphatic halogenated compounds, nitro compounds, or oxygen compounds. This is a high-temperature-temperature process, but the conditions required are milder than those in the noncatalytic method. The average alkylation temperature is about 752° F. and the pressure is about 3000 pounds, gauge,



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for the alkylation of isobutane with ethylene, and about 4500 pounds, gauge, when propylene is the olefin used. Both normal and isoparaffins can be alkylated by this procedure. The structure of the synthetic hydrocarbons corresponds in general to what would be expected as a result of the interaction between tertiary or secondary carbon atoms of paraffins and unsaturated carbon atoms of olefins. Alkylation of n-butane with ethylene produces predominantly 3-methylpentane. Alkylation of isobutane with ethylene gives neohexane; isopentane alkylated with ethylene yields 3,3-dimethylpentane, and isobutane with propylene gives 2,2-dimethylpentane with 2-methylhexane and triptane in smaller yields. The apparatus used in the work is described, and the results are presented in considerable detail in 13 tables. A bibliography of 13 references is also included.

The Structure of Ethylene Polysulfides. H. E. WESTLAKE, JR., M. G. MAYBERRY, M. H. WHITLOCK, J. R. WEST, AND G. J. HADDAD, *Jour. Amer. Chem. Soc.* **68** (1946) pp. 748-51.

The authors note that although the reaction of sulfur with several of the higher olefins has been studied, ethylene, the simplest unsaturated compound, seems to have been largely neglected. They find that extensive reaction occurs between ethylene and sulfur at temperatures above the melting point of sulfur. Ethylene reacts with sulfur with or without solvents or pressure to form a xylene-insoluble polymer and a soluble oil, part of which is volatile. The various products obtained were studied and structures postulated from the experimental evidence.

The Relative Efficiency of Some Polymerization Inhibitors. R. L. FRANK AND C. E. ADAMS, *Jour. Amer. Chem. Soc.* **68** (1946) p. 908.

This study of inhibitors was carried out under the sponsorship of the Office of Rubber Reserve. Considerable losses often occur in the preparation of vinyl monomers due to their ease of polymerization, especially during distillation. Little variation was found in the order of inhibitory strength from one monomer to another, that is, a good inhibitor for one monomer is likely to be good for another. One fact stood out in the results, namely that two of the most widely used inhibitors, phenyl-B-naphthylamine and t-butylcatechol, are among the poorest in inhibitory action. Picric acid and trinitrobenzene were used with great success during distillation of a variety of monomers. Picric acid, however, should not be used in metal vessels. The authors feel that the use of traces of polynitro compounds involves no danger.

Manufacture: Processes and Plant

Heat Transfer and Friction of Water In an Annular Space. F. G. CARPENTER, A. P. COLBURN, AND E. M. SCHOENBORN, *Trans. Amer. Inst. Chem. Engrs.* **42** (1946) pp. 165-187.

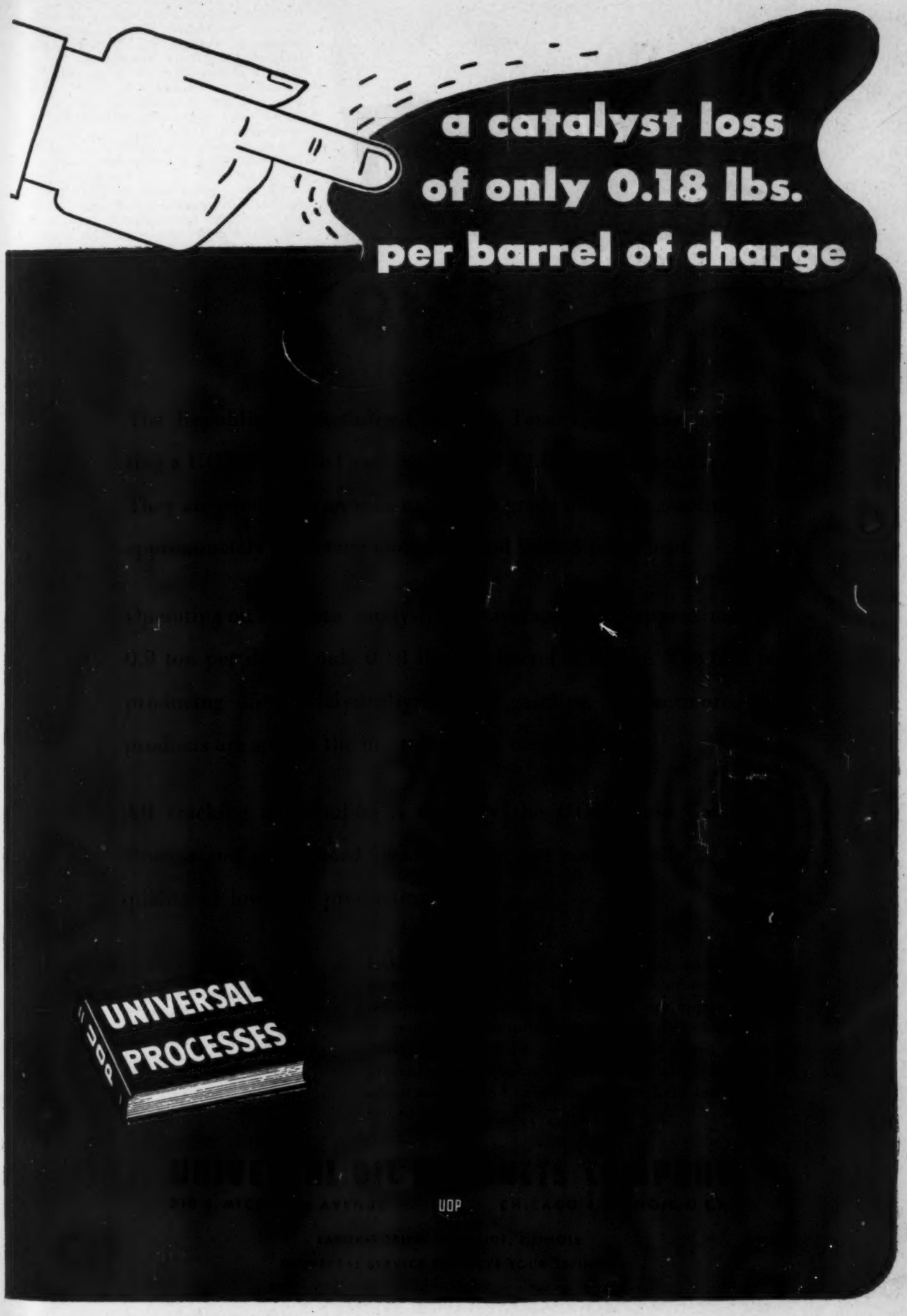
The uncertainties existing in the methods for predicting heat-transfer coefficients for fluids flowing in annular spaces, paritcularly in the transition region from viscous to turbulent flow, led to the experimental study of water flowing upwards in a narrow annular space. The authors present data for heat transfer and isothermal pressure drop for water flowing in the annulus formed between a ⅝-inch O.D. and 0.834-inch I.D. copper tube 8 feet long and arranged vertically. The friction data secured in the course of the work indicate that the proper choice of diameter to be employed in evaluating Reynolds numbers is the equivalent diameter. Using the equivalent diameter, the transition from viscous to turbulent flow occurs at approximately 2000, which is similar to that for flow inside tubes. In the viscous region the values of the friction factor were in excellent agreement with the theoretical relationship. Data taken in the turbulent region fall on the literature line for commercial pipe. The heat-transfer data cover a range of Reynolds number, based on equivalent diameter, from 150 to 15,000. At the highest Reynolds numbers, the data approach correlation for circular tubes. At the lower Reynolds numbers, the annular data fall somewhat under those for circular tubes. In the viscous region, in which few data for annuli flow are to be found, the results are shown to be slightly higher than relations for flow inside tubes.

Thermodynamic Evaluation of Binary and Ternary Liquid Systems. K. WOHL, *Trans. Amer. Inst. Chem. Engrs.* **42** (1946) pp. 215-49.

In order to obtain knowledge of vapor-liquid equilibria with a minimum of experimental data, equations for the activity coefficients in the liquid solution are required. Such equations are particularly needed in the case of non-ideal multicomponent systems such as are encountered in azeotropic and extractive distillation. Various equations have been proposed, but the form in which they are given frequently makes their application difficult and the diversity of their forms adds to the difficulty of choice between the various equations. The author presents equations for the activity cofficients in binary and ternary liquid solutions, these being of the types of van Laar, the Margules, the Scatchard-Hamer, and those of a more general type as well. They are given in their simplest form at first, in which only the second power of the mole fractions is used, and later in forms in which the third and fourth powers are used. All of them are written so that they appear as variations of one mathematical scheme so that transition from one to another is obvious. All contain as principal constants the end values of the activity coefficients in the binary systems, which the author believes should simplify their practical application. The probable range of validity of the equations presented is considered.

A Simplified Method for Solving Multicomponent Distillation Problems. R. J. HENGSTEBECK, *Trans. Amer. Inst. Chem. Engrs.* **42** (1946) pp. 309-329.

A simple graphical method is pre-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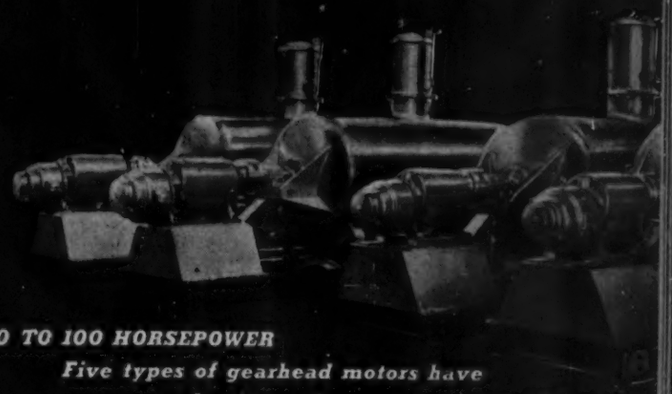
sented for solving multicomponent distillation problems. The procedure is similar to that of the McCabe-Thiele method for binary separations. It applies to systems for which the usual assumptions of constant molal overflows are valid and in which there are no intermediate components between the key components. A modification is given for the calculation of separations of groups of components, as in depropanization or debutanization. In addition to being quick and accurate the method has the further advantage of locating the feed tray directly. In the method presented the multicomponent system is reduced to an "effective" binary system by the use of certain approximations, and the number of plates required for the desired separation is determined graphically for an arbitrarily assumed reflux ratio. The method is applied to nine cases, for each of which it is checked by rigorous calculation. For the cases studied, the average deviation in the number of trays calculated by the author's method from the number calculated rigorously was only 0.5 theoretical plate. The maximum deviation was 0.8 theoretical plate.

Extractive Distillation—Separation of C_4 Hydrocarbons Using Furfural. J. HAPPEL, P. W. CORNELL, DUB. EASTMAN, M. J. FOWLE, C. A. PORTER, AND A. H. SCHUTTE, *Trans. Amer. Inst. Chem. Engrs.* **42** (1946) pp. 189-214.

The process used by the Neches Butane Products Company for the separation of C_4 hydrocarbons is described. Furfural was employed as an extractive distillation medium in the making of three separations: isobutane from butene-1, n-butane from butene 2's, and butene-1 from butadiene. The operation of the equipment is discussed, and test data are given showing typical performance. The best separation is obtained for any given solvent circulation when the highest proportion of hydrocarbon is used that can be dissolved in the solvent without causing the separation of a hydrocarbon rich phase. The method for obtaining this optimum condition is considered and discussed. The process used and the equipment gave excellent performance. The tests indicated an average tray efficiency of approximately 25 percent. New methods were developed for calculating tray efficiencies from test data and for the estimation of activity cofficients in multicomponent solutions from binary data. The authors believe that these have general applicability. A bibliography of 13 references is included.

Mechanism of Solvent Action. A. K. DOOLITTLE, *Ind. & Eng. Chem.* **38** (1946).

The size and shape of the solvent molecule influence the temperature coefficient of solvent capacity as this is judged by measuring the threshold concentration for solvation at different temperatures. In the range of temperature +50 to −10° C. small straight-chain molecules exhibit normal behavior and are better solvents as the temperature rises, but long-chain molecules of the same homologous series behave in the opposite manner and are better solvents when cold than when hot. For solvent molecules of the same molecular weight, it is found that shape is the determining factor; compact structured molecules show a normal temperature dependence of solvent ability, and extended mole-



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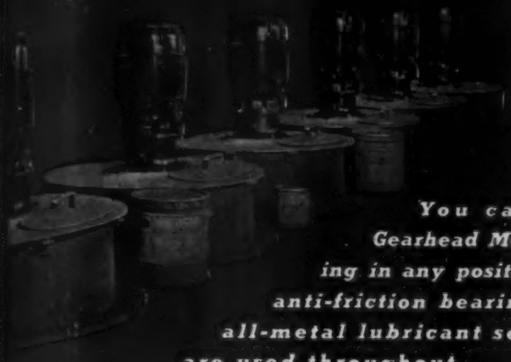

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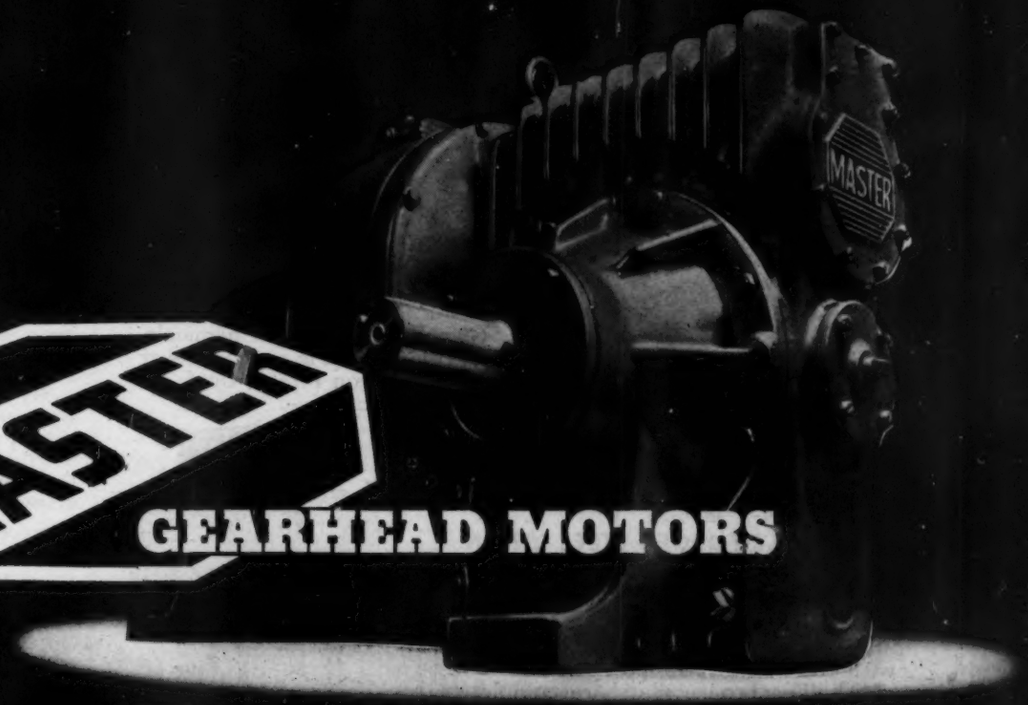

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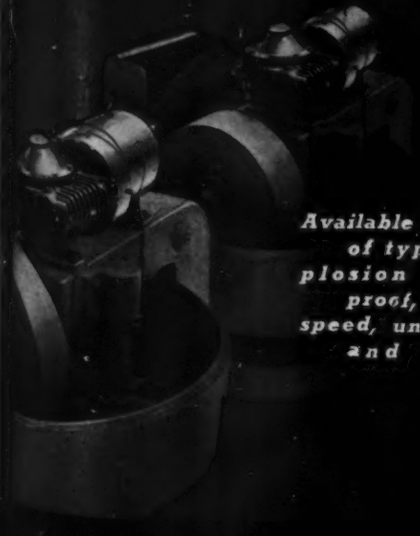

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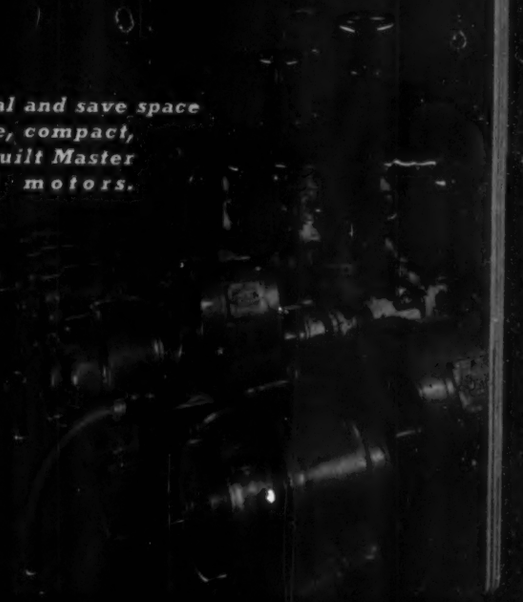

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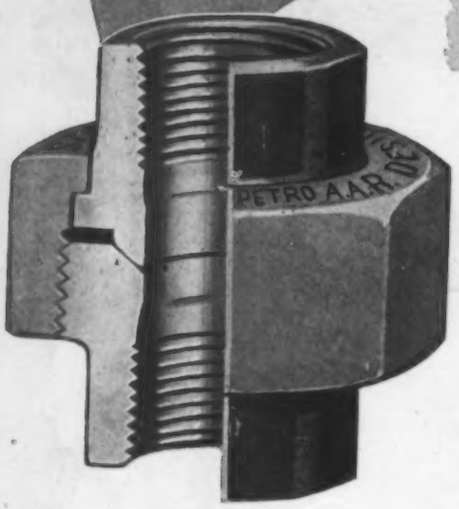

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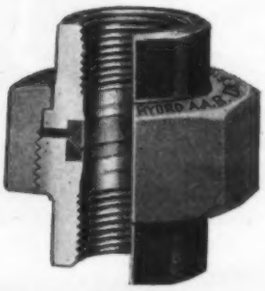

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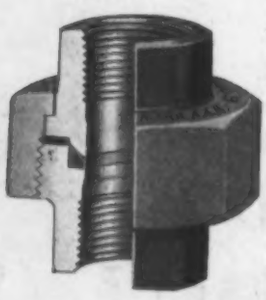

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cules show the inverted temperature behavior. Certain solvents showing the inverted temperature behavior are used to prepare gels of macromolecular substances that liquefy on cooling. The data secured in the investigation are presented in considerable detail in both tabular and in graphical form.

Liquid-Liquid Extraction in Spray Towers. H. F. JOHNSON, JR., AND H. BLISS, *Trans. Amer. Inst. Chem. Engrs.* **42** (1946).

Towers used industrially for the countercurrent extraction of liquid-liquid systems are of three principal types: spray, packed, and perforated plate. The latter two have received more attention than the first. The authors made 109 extraction runs with four systems in a 1.824-inch I.D. spray-type tower. Emphasis was placed on the determination of the extraction coefficient, Ka, and on distribution, and some attention was given to the flooding phenomenon. It was found that Ka increases with both dispersed and continuous phase flow rates, increases slightly with increases in entering solute concentration, and tends to decrease somewhat with increase in tower length. When the extraction is from continuous to dispersed phase, Ka is greater and drop coalescence is less than when extraction is in the other direction. The design of distributors is considered and discussed. Correlation methods for predicting overall coefficients for one system in a given spray tower from data taken with another system in the same apparatus are suggested. Comparisons are made of spray, packed, and perforated plate towers and the conditions under which the spray tower may be advantageous are deduced from these considerations. In general, the spray tower finds its best utility in the extraction of rather simply separated systems that do not require large tower heights, but for which volumetric flows are large so that the high throughput advantage in the spray columns can be realized.

Successive Multiple-Contact Extraction Nomograph. M. NORD, *Ind. & Eng. Chem.* **38** (1946) p. 560.

In liquid-liquid extraction in which the ideal distribution law applies, the equation for succesisve multiple-contact extraction is

$$x_n = \left(\frac{H}{H+SD}\right)^N x_o$$

in which x_o = weight of solute per pound of inert component in feed, x_n = the weight of solute per pound of inerts in the final raffinate, H = weight of inserts (constant), S = weight of extracting solvent per stage (constant), N = number of contacts, and D = distribution coefficient. The equation applies to the type of extraction in which the total quantity of solvent used is divided into several equal portions. The feed is treated with the first portion and the raffinate from this extraction is then treated with a second portion of the fresh solvent, etc. A nomograph is presented that gives a graphical solution of the equation.

Purification of Commercial Benzene by Azeotropic Distillation. J. GRISWOLD AND R. H. BOWDEN, *Ind. & Eng. Chem.* **38** (1946) pp. 509-12.

The work reported was an introductory study of the azeotropic purifica-

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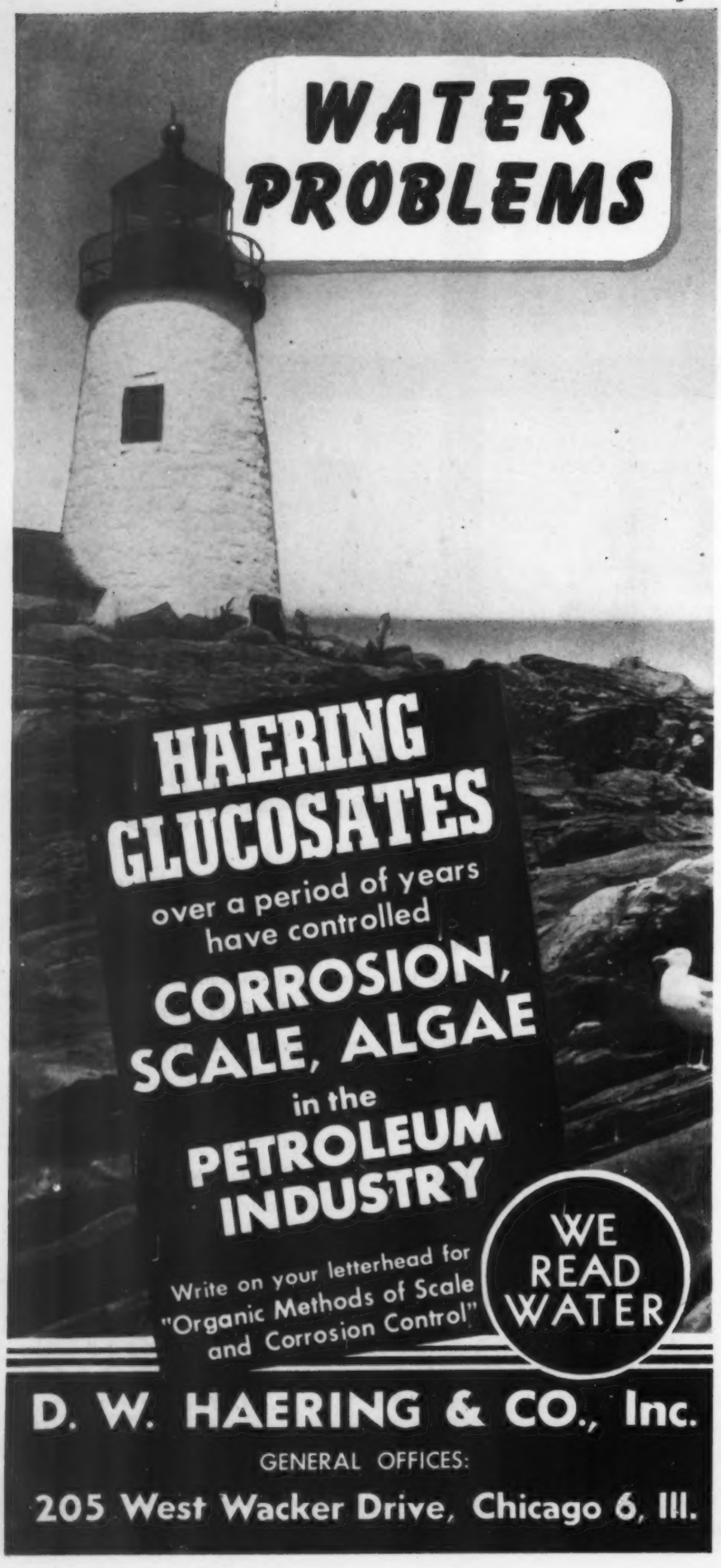
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tion of a commercial coke-oven benzene with acetone, and included an analytical study of the separated impurities. A 12-plate column, 6 inches in diameter, was used in the work, along with a laboratory column 1 inch in diameter and packed for a length of 48 inches with 3 mm. single-turn helices. The impurities found were mainly cyclohexane, C_7 paraffins, and naphthenes. n - Heptane and dimethylcyclopentanes predominated. The approximate purity of the original benzene was 98.5 percent. Benzene of approximately 99.7 percent purity can be readily prepared by azeotropic distillation of the commercial benzene with acetone. A bibliography of 11 references is included.

Catalytic Gasification of Higher Hydrocarbons. C. H. Riesz, V. I. Komarewsky, L. J. Kane, F. Estes, and P. Lurie, *Am. Gas Assoc. Monthly* **28** (1946) pp. 159-64.

Hydrocarbons, such as propane, have been recently employed for making hydrogen and carbon oxides by reaction with steam. Experiments were conducted with propane at 1200° F. to investigate whether a gas having a heating value of 550 Btu. could be made by incomplete conversion. However, it was found that a gas of about 300 Btu was produced under any conditions that prevented carbon deposition on the catalyst. Unless the carbon of the propane is completely utilized by blue gas reaction, carbon difficulties were encountered. Catalysts used completed the reaction with steam, whether in the presence or absence of air, at temperatures as low as 1200° F. Olefins were not found in the partially cracked gas, but it is not determined whether this was the effect of low temperature or whether the catalyst served to hydrogenate the olefin. Blue gas made can, of course, be enriched to any desired thermal value by the addition of propane or butane vapors. Specific gravity can be controlled by regulating the amount of air used in the reforming operation, or air or products of combustion can be employed as a diluent for the blue gas produced when using only steam for the reforming. The utilization of the higher hydrocarbons for complete gasification is also discussed.

Process Design of Catalytic Reactors—Dehydrogenation of Butane. R. H. Dodd and K. M. Watson, *Trans. Amer. Inst. Chem. Engrs.* **42** (1946) pp. 263-91.

The authors describe a pilot plant designed and built for a study of catalytic processes. The design is such as to permit operation over wide ranges of conditions and on many systems employing solid catalysts. The plant can be operated either as an "integral reactor," to simulate the results of a commercial reactor, or as a "differential reactor" for the direct determination of absolute reaction rates. Equipment of this type, combined with sound thermodynamic and kinetic principles, permits the establishment of optimum process conditions from a relatively few small-scale experiments. In many cases the usual pilot-plant and semi-commercial experimentation can be omitted and optimum large-scale equipment designed directly from fundamental kinetic measurements. The equipment was first used in a study of the dehydrogenation of butane over a chromia-alumina catalyst. The rate of dehydrogenation was found to be con-

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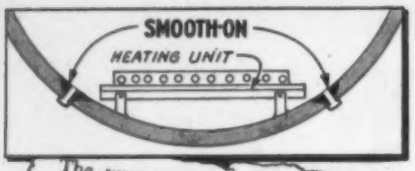

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trolled by a surface reaction involving dual active centers. The overall selectivity of the reaction is reduced by the cracking of both butane and butenes. Equations were developed that permit partial prediction of the results of commercial reactors over a wide range of conditions. These equations were integrated for isobaric, isothermal reactors to show the variation of conversion and selectivity with temperature, pressure and space velocity. More data are needed before a complete and rigorous analysis can be made.

Hydrogen by the Steam-Hydrocarbon Process. *Chem. & Met. Engr.* **53** (1946) pp. 122-3, 162-5.

The steam-hydrocarbon process for the production of hydrogen has increased rapidly in importance so that at present the hydrogen manufacturing capacity in the United States of the plants employing this process is over four billion cubic feet of hydrogen per month. This is exceeded only by the steam-water gas process, with an installed capacity of six billion cubic feet of hydrogen per month, most of which is in older plants. Several different hydrocarbons are used, such as natural gas, refinery gas, propane, and butane. The first operation is the removal of sulfur compounds if any are contained in the hydrocarbons. The desulfurized hydrocarbon is mixed with steam, and passed through a furnace where it is heated to about 1500° F. The furnace tube system is made of alloy steel and externally heated, and filled with a catalyst that promotes the conversion of hydrogen and steam to oxides of carbon and to hydrogen. Steam is added at the furnace outlet to cool the gas to about 750° F. before it enters a carbon monoxide converter containing an iron oxide catalyst that promotes the oxidation of carbon monoxide to carbon dioxide and hydrogen. The gas is then cooled and flowed through a carbon dioxide absorber. One process employs aqueous amine solutions in a continuous regenerative manner for the removal of carbon dioxide from the hydrogen. Since carbon monoxide is an active poison for the nickel catalysts employed in many types of hydrogenation, the carbon monoxide content of the hydrogen is reduced further by oxidation followed by carbon dioxide removal. The hydrogen made by the process is more than 99.9 percent pure and contains less than 0.01 percent of carbon monoxide and carbon dioxide and less than 0.1 percent of residual hydrocarbon.

Products: Properties and Utilization

Determination of Tetraethyl Lead in Gasoline by X-Ray Absorption. M. V. Sullivan and H. Friedman, *Ind. & Eng. Chem., Anal. Ed.* **18** (1946) pp. 304-6.

The use of tetraethyl lead to bring various base stocks up to a set standard of quality requires the addition of varying amounts of lead to various lots of fuel. Control in manufacture and by the user may involve the determination of the lead content of hundreds of samples of gasoline per day. No chemical method has been proposed that does not require excessive time. An x-ray absorption technique is used by the authors, along with a Geiger counter to detect the radiation. The result is a method for the quantitative determination of lead that is equivalent to the chemical analysis in accuracy, but that can be completed by an unskilled worker in 5 minutes. The apparatus used, and also the procedure, are described in sufficient detail. Although the measurements in the work were made on leaded and unleaded gasoline, the method of analysis is applicable to the determination of lead in any other medium of low atomic number. A bibliography of 5 references is included.

Determination of Small Amounts of Aromatic Hydrocarbons in Aqueous Solutions. H. E. Morris, R. B. Stiles, and W. H. Lane, *Ind. & Eng. Chem., Anal. Ed.* **18** (1946) pp. 294-5.

The determination of aromatic hydrocarbons in plant effluents or other aqueous solutions is a problem not infrequently encountered. A method is described that uses formaldehyde-sulfuric acid reagent for the determination of 1 to 500 p.p.m. of aromatic hydrocarbons in aqueous solutions. The accuracy of the method is +10 percent. The sensitivity of the test is 0.0001 gram of aromatic hydrocarbon. The preparation of the reagent and the procedure to be followed in the test are described.

Assembly and Calibration of a Density Balance for Liquid Hydrocarbons. A. F. Forziati, B. J. Mair, and F. D. Rossini, *J. Res. Natl. Bur. Standards* **35** (1945) pp. 513-9. Res. Paper RP1685.

The authors describe the assembly and calibration of a density balance for the rapid measurement of densities of liquid hydrocarbons on samples as small as 9 milliliters. Measurements can be reproduced to ± 0.00002 to ± 0.00003 grams per milliliter and the over-all uncertainty of the measurements is estimated to be ± 0.00005 grams per milliliter.

Standards Completed On 90 Hydrocarbon Compounds

The National Bureau of Standards has completed standard samples on 90 hydrocarbon compounds under a cooperative program undertaken in 1943 at the request of the Petroleum Industry War Council.

The program is being carried out under the API Research Project 46 Committee on Hydrocarbons for Spectrometer Calibration at the Bureau of Standards, Ohio State University and Pennsylvania State College.

In addition to the 90 standard samples completed, 32 compounds are in process of purification, 35 are on hand for purification, and 30 are in process of synthesis or purchase.

The bureau pointed out that, with several exceptions, the cooperative program has reulted in much purer samples of these hydrocarbons than had ever before been prepared, and also in the preparation of seevral compounds which had never before been made.

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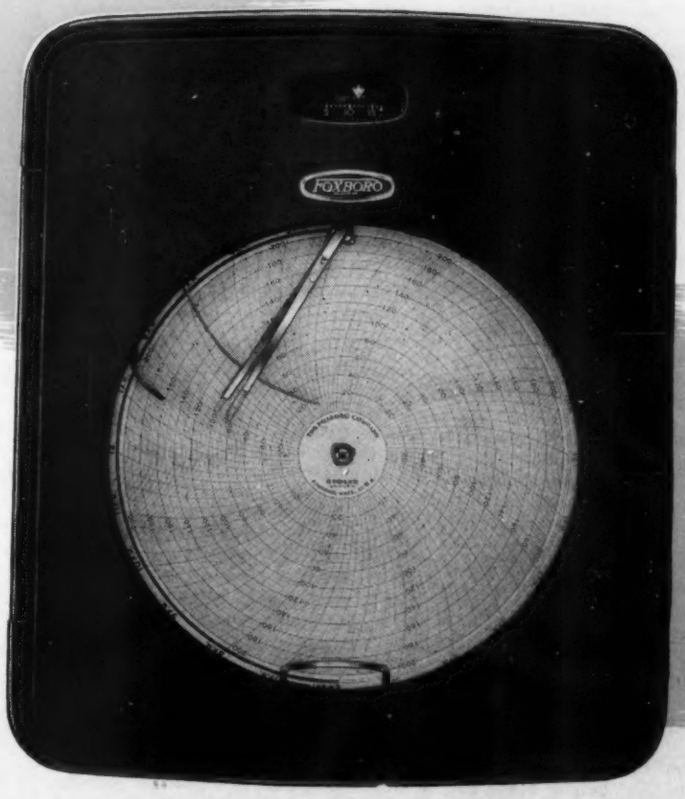

Write for complete explanation in Bulletin 381. The Foxboro Company, 74 Neponset Avenue, Foxboro, Mass., U.S.A.

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Digest of Recently Issued United States

Patents Pertaining to Petroleum Refining

Compiled by HEINZ HEINEMANN

CRACKING AND REFORMING

U.S.P. 2,398,819. Conversion of Hydrocarbons. L. W. Cook to The Texas Company.

A hydrocarbon mixture containing both paraffinic and naphthenic hydrocarbons is subjected to catalytic cracking by the substantially simultaneous action of individual catalysts for paraffins and naphthenes. The vapors are passed through a zone containing two catalysts, one comprising a compound containing 80 percent SiO_2, 15 percent MgF_2, and 5 percent AlF_4. ½ H_2O, the other consisting of alumina impregnated with boron oxide. The reaction is carried out at 800-1050° F.

U.S.P. 2,399,174. Conversion of Hydrocarbons. H. O. Folkins to The Pure Oil Company.

Hydrocarbons are subjected to cracking at a temperature between 375-750° C. in the presence of small amounts of phosphorus oxyhalide and oxygen or gas containing free oxygen such as air. A total of 0.5 to 6 mol percent of oxygen and phosphorus oxyhalide are present in about equimolecular amounts.

U.S.P. 2,399,540. Precombustion Cracking Process. D. E. Carr to Union Oil Company of California.

A hydrocarbon-conversion process is described which consists of burning a fuel containing a metallic-organic compound (such as an organic acid soap) and thereby forming combustion gases having a temperature of 2000-3500° F. which contain finely divided metal oxide. These gases are mixed with a hydrocarbon fraction in such proportions that the resulting mixture has a temperature of 900-1600° F. The mixture is passed to a reaction zone, left at reaction temperature for 0.1-5 seconds and is then cooled. Hydrogen may be introduced along with the hydrocarbons.

U.S.P. 2,399,781. Manufacture of Toluene. G. B. Arnold to The Texas Company.

Aromatic hydrocarbons or hydrocarbon oils rich in aromatics are subjected to cracking in the presence of a metallic fluoride catalyst to effect conversion into lower-boiling hydrocarbons containing a large proportion of benzene. The cracked products or fractions thereof containing the benzene are subjected to conversion in contact with a catalyst capable of catalyzing the benzene exchange reaction to produce toluene. The fluoride catalyst should be non-volatile at temperatures below 1200° F.

U.S.P. 2,399,805. Production of Aviation Gasoline. P. E. Hurley, and J. B. Dunlap to Shell Development Company.

A process for increasing the aromatic content of straight-run naphthas substantially free from C_4 and lighter hydrocarbons and boiling below 500° F. is described which comprises the steps of non-catalytically cracking the naphtha in the pseudo liquid phase at 1000 to 1040° F. and under 500-1000 psi, separating from the resulting products a second naphtha fraction substantially free from C_5 and lighter hydrocarbons and boiling below 450° F., non-catalytically cracking in the pseudo liquid phase at 1030-1100° F. under 250-750 psi a mixture of the second fraction and a portion of a third fraction produced in the process, separating from the resulting product a third fraction free from C_5 and lighter hydrocarbons and boiling below about 400° F. and recycling a portion of the third fraction.

U.S.P. 2,400,075. Manufacture of Gasoline Hydrocarbons. W. F. Claussen to The Texas Company.

Hydrocarbon are cracked at 850-1000° F. with a catalyst consisting of Doucil impregnated with nickel, producing gasoline, hydrogen and carbonaceous matter upon the catalyst. The catalyst is purged periodically and regenerated by passage of CO_2 at 1000-1300° F. A gas rich in carbon monoxide is formed and is utilized in a Fischer-Tropsch reaction zone to react with hydrogen formed in the cracking step.

U.S.P. 2,400,194. Method for Contacting Fluids with Finely Divided Solid Particles. R. B. Day and E. R. Kanhofer to Universal Oil Products Company.

A continuous bed of solid particles is maintained in a confined reaction zone and particles are caused to move downwardly through the reaction zone, fresh particles being supplied to the top, spent particles being withdrawn from the bottom of the zone. A stream of fluid is charged to the top of the zone and passed downward through the upper portion of the bed. A region of enlarged horizontal cross section is provided in the lower portion of the reaction zone and bed, causing a reversal in direction of flow of the fluid and causing fluid to be discharged upwardly from the zone.

U.S.P. 2,400,431. Production of Catalytically Cracked Gasoline. G. C. Montgomery and R. W. McOmie to Shell Development Company.

In a process for the production of normally gaseous hydrocarbon products and normally liquid hydrocarbon products of the nature of gasoline from hydrocarbon oils containing nitrogen compounds by catalytic cracking with a clay-type catalyst, the combination of process steps is claimed comprising condensing the major portion of the normally liquid hydrocarbons of the nature of gasoline from the vaporous cracked products of said catalytic cracking treatment in the presence of added water, compressing the uncondensed vapors to a pressure of at least 3 atmospheres, intimately contacting said vapors while in the compressed state with a molecular excess of water thereby to extract cyanides, separating said water containing extracted cyanides and contacting the compressed gas with the first liquid hydrocarbon condensate under rectified absorption conditions.

U.S.P. 2,400,446. Catalytic Treatment of Hydrocarbon Oils. P. L. Veltman to The Texas Company.

Compositions comprising a hydrated AlF_3 in combination with a catalytically active material, particularly one that is porous in structure, constitute catalysts which are particularly valuable in the cracking and reforming of hydrocarbons.

ISOMERIZATION

U.S.P. 2,399,354. Isomerization. J. Kellett, M. M. Marisic and A. A. O'Kelly to Socony-Vacuum Oil Company.

Hydrocarbons to be isomerized are contacted in the vapor phase with an inorganic oxide adsorbent material having a high cracking activity as measured by conversion of gasoil under moderate cracking conditions. Temperatures employed are in the neighborhood of the minimum temperature at which cracking of the hydrocarbons to be isomerized will be initiated.

U.S.P. 2,399,765. Isomerization of Light Naphtha Paraffinic Hydrocarbons. B. H. Shoemaker and B. L. Evering to Standard Oil Company (Indiana).

The method of isomerizing paraffin hydrocarbons of the pentane-hexane boiling range which method comprises separating said hydrocarbons into a pentane fraction and a hexane fraction, removing isopentane and lighter hydrocarbons from the pentane fraction, contacting the remaining normal pentane in the absence of any substantial amount of added hydrogen but in the presence of a small amount of a cyclic cracking inhibitor with a column of a halide isomerization catalyst under conditions of temperature, pressure and space velocity to give isomerization as the main reaction in a pentane contacting zone, removing catalyst from the products of the contacting step, contacting said hexane fraction with a hydrogen chloride-containing gas stream for absorbing hydrogen chloride therefrom, contacting the hexane together with absorbed hydrogen chloride with a second column of halide isomerization catalyst in a hexane contacting zone under substantial hydrogen pressure and under conditions of temperature, pressure and space velocity to effect isomerization as the main reaction, separating catalyst and a hydrogen chloride gas stream from products leaving the hexane contacting step, returning said gas stream to said absorption step, removing from said product stream hydrocarbons which boil substantially above about 175° F., combining the remainder of the product stream with the pentane isomerization product stream, depentanizing the com-

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bined products and introducing said pentanes to said isopentane, removal step, fractionating the depentanized products to separate neohexane from heavier hydrocarbons and returning said heavier hydrocarbons to said hexane contacting step.

U.S.P. 2,399,833. Isomerization Process. N. F. Myers to Standard Oil Development Company.

Normal paraffins containing at least four C atoms are isomerized in the presence of $AlCl_3$ and HCl at 250-350° F. in the vapor phase, after the feed stock containing the normal-paraffins has been pretreated with sulfuric acid of 85-100 percent concentrate, to remove impurities deleterious to the isomerizing activity of the catalyst. The acid-treated stock is, prior to isomerization, treated with bauxite at 50-150° F. to remove sulfur bodies from the isomerization charge.

U.S.P. 2,399,927. Production of Isoparaffins. D. A. Howes and E. W. Fawcett to Anglo-Iranian Oil Company, Ltd.

Normal-butane or normal-pentane are isomerized in the absence of added hydrogen at 200-600° C. and under a pressure of from 20-50 atmospheres in the presence of a catalyst consisting of at least one compound selected from the group consisting of the oxides and sulfides of metals of Group VI of the periodic table and at least one compound selected from the group consisting of the oxides and sulfiides of metals of Group VIII of the periodic table. A recommended catalyst consists of tungsten disulfide and silica gel.

ALKYLATION

U.S.P. 2,400,090. Hydrocarbon Isomerization. R. W. Henry to Phillips Petroleum Company.

Paraffins can be isomerized by passage over a supported Friedel-Crafts type catalyst of relative uniform activity. However, in such a system, longer reaction times are necessary as equilibruim is approached and the amount of isomerized products in the hydrocarbon mixture increases. The rate of reaction can be increased by increasing the concentration of hydrogen halide promoters. An increasing hydrogen halide concentration is maintained throughout the reaction zone.

U.S.P. 2,398,869. Alkylation of Hydrocarbons. E. W. Thiele to Standard Oil Company (Indiana).

A countercurrent multi-stage alkylation system employing an $AlCl_3$-hydrocarbon complex catalyst is described. The catalyst is prepared from aromatic-free naphtha and $AlCl_3$. It is introduced into the mixer of a last alkylation zone, passed through the reactor and settler and is then introduced into the mixer of the one before the last zone.

U.S.P. 2,398,905. Alkylation of Isoparaffinic Hydrocarbons. C. B. Linn to Universal Oil Products Company.

Isoparaffins are contacted with olefins in the presence of a catalyst consisting of a major proportion by weight of liquid HF and a relatively minor proportion by weight of a diluent or spacing agent selected from a group of substantially non-oxidizing compounds com-

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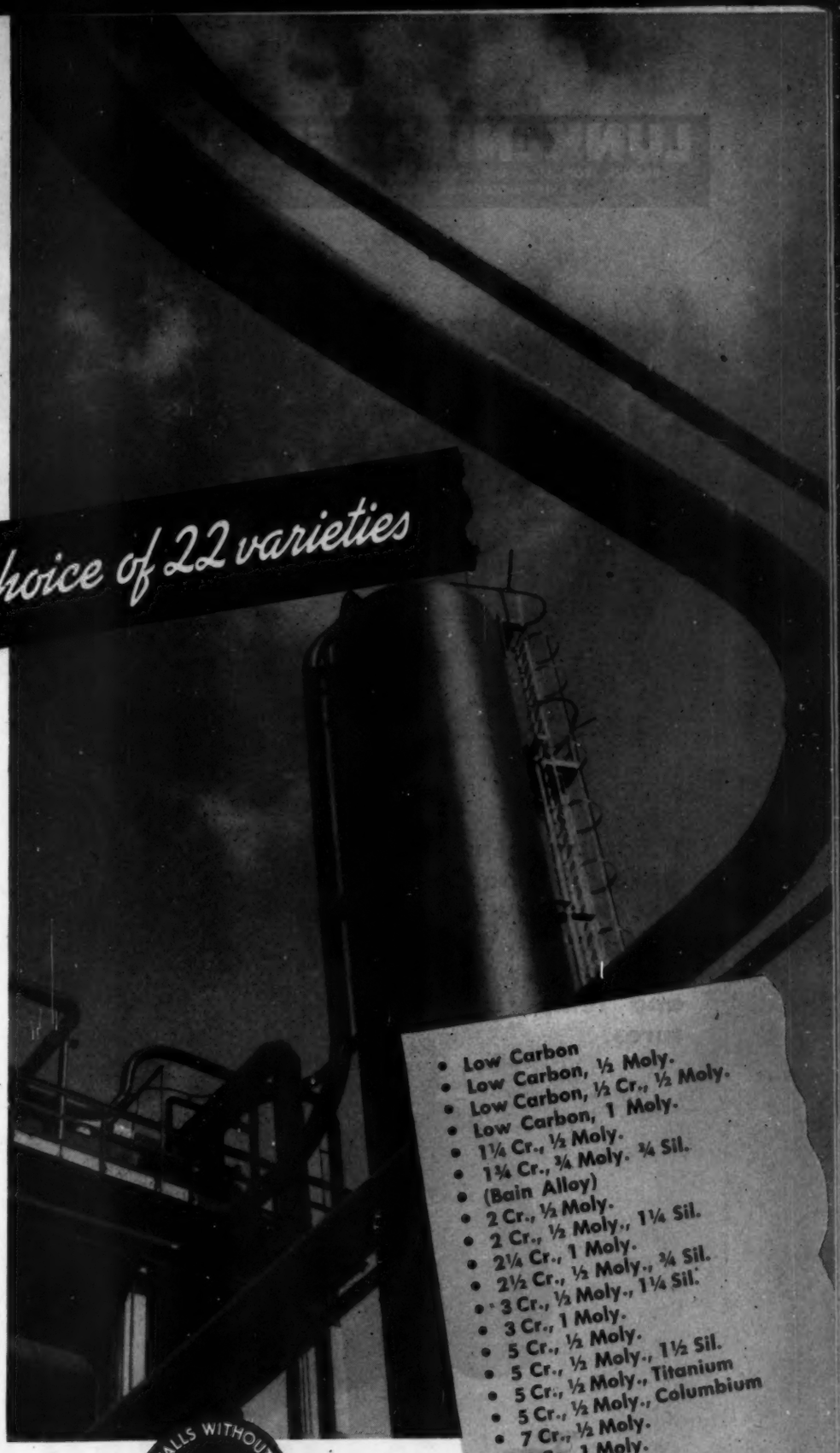

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- 2 Cr., ½ Moly., 1¼ Sil.
- 2¼ Cr., 1 Moly.
- 2½ Cr., ½ Moly., ¾ Sil.
- 3 Cr., ½ Moly., 1¼ Sil.
- 3 Cr., 1 Moly.
- 5 Cr., ½ Moly.
- 5 Cr., ½ Moly., 1½ Sil.
- 5 Cr., ½ Moly., Titanium
- 5 Cr., ½ Moly., Columbium
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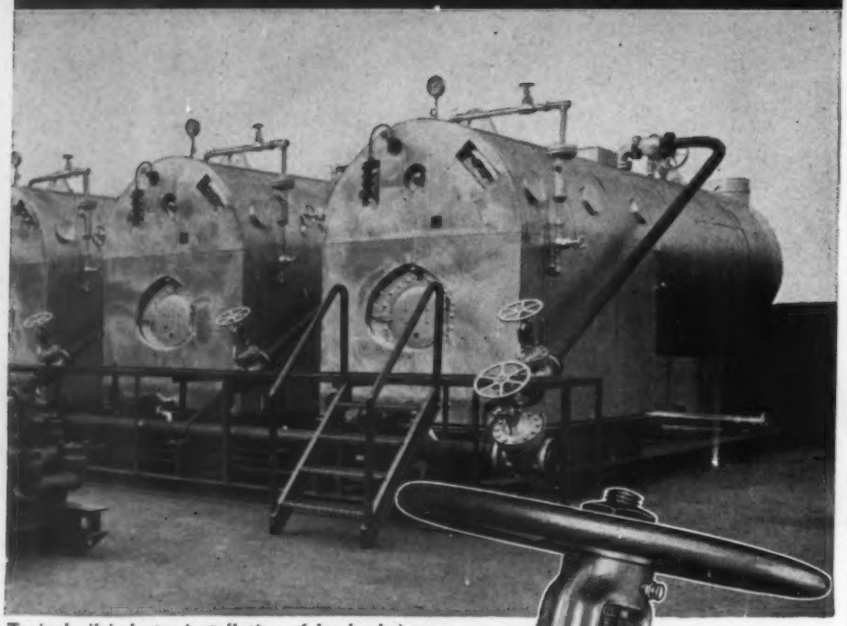

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prising organic acids, acids of phosphorus, hydroxyfluoboric acids, and also anhydrides and esters of said acids. Temperatures of —30 to 100° C. are employed.

U.S.P. 2,399,240. Alkylation of Isoparaffins with Olefins. S. H. McAllister, J. Anderson and W. E. Ross to Shell Development Company.

It has been found that improved alkylation results are obtained by treating olefinic feed stocks with acid so as to remove along with impurities such as diolefins a regulated amount of the mono-olefin. Sulfuric acid of 60-70 percent concentration is employed at 30-50° C. in a controlled acid: hydrocarbon ratio of at least 0.5:1. The acid treated hydrocarbons are neutralized with dilute NaOH solution and redistilled prior to alkylation.

U.S.P. 2,399,353. Alkylation Process. J. P. Jones to Phillips Petroleum Company.

Lower-boiling iso-paraffins and ethylene are contacted at 150-350° F. with liquid concentrated HF and finely divided nickel, iron or cobalt as the essential catalytic material. Reaction conditions are such that alkylation of paraffin and olefin is a minor reaction and reaction of paraffin to form a higher-boiling paraffin and concomittant hydrogenation of ethylene to ethane is a major reaction. Ethane is separated from the reaction products, dehydrogenated, and ethylene is recycled.

U.S.P. 2,399,368. Production of Paraffin. M. P. Matuszak to Phillips Petroleum Company.

Propylene and iso-butane are converted to propane and octanes by admixing propylene at 100-200° F. with a liquid mixture of iso-butane and HF, the HF comprising between about 2 to 6 percent by weight of the mixture, in an amount such that the mol ratio of HF to olefins is between about 1.0:1 and 1.2:1, maintaining the mixture for 5 to 15 minutes in contact, then adding and admixing additional HF in an amount such that the volume ratio of total liquid HF to total hydrocarbon is between about 0.3:1 and 2:1 and maintaining the last named admixture at a reaction temperature between 100 and 200° F. for not more than 30 minutes.

U.S.P. 2,399,662. Process of Alkylating Aromatic Hydrocarbons. R. E. Burk and E. G. Hughes to The Standard Oil Company (Ohio).

One mol of ethylene and 3-15 mols of benzene are alkylated at 200°F. and under at least 50 psi pressure in the presence of a vaporized catalyst consisting of a large amount of HF and a small amount of BF_3. Cool benezene is fed to the reaction countercurrently to the off-gas to absorb fluorides and reintroduce them to the reactor.

U.S.P. 2.400,367. Alkylation Process. K. Opryshek and J. N. Chatfield to Standard Oil Development Company.

A mixture comprising olefins, isoparaffins and a catalyst such as sulfuric acid of 80-100 percent concentration is passed into the bottom of a reaction zone maintained under alkylation conditions. A stream containing alkylated products and catalyst is withdrawn from the upper section of the zone. Catalyst is separated and recycled to the bottom of the zone. A catalyst emulsion is with-

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Cadmium
Calcium
Lime
Coke
Electrode Coke
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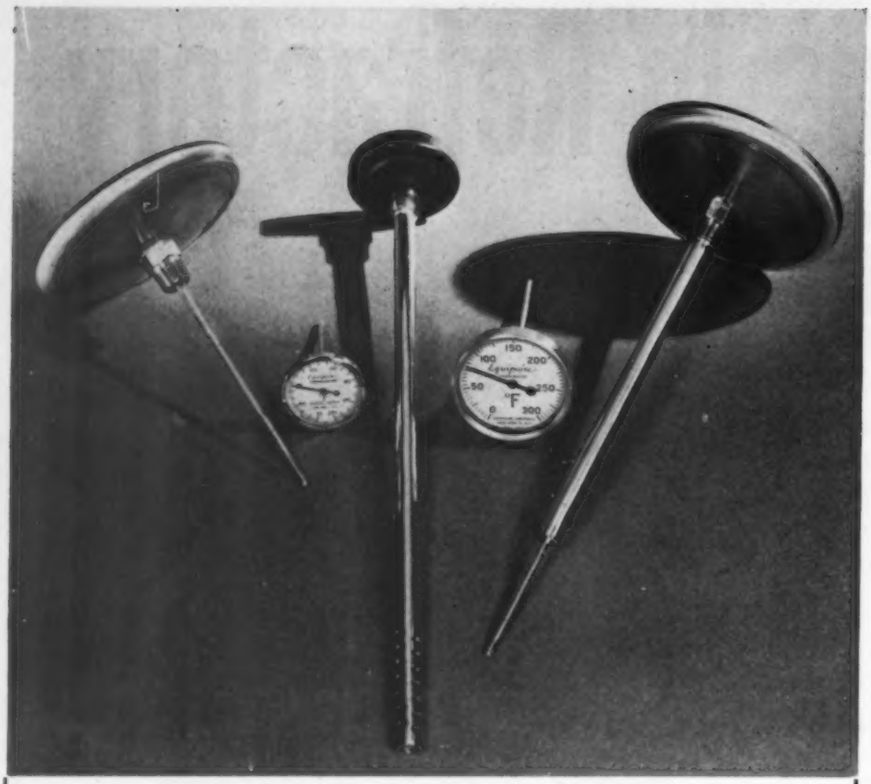

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drawn from an intermediate section of the zone and is also recycled to the bottom of the zone.

U.S.P. 2,400,386. Hydrogen Fluoride Alkylation of Paraffins. J. C. Bolinger, A. K. Brumbaugh and J. H. Curtis to Socony-Vacuum Oil Company.

The invention is concerned with that stage of an alkylation process in which the hydrocarbon phase is heated and partially distilled to remove acid and the acid is returned to the contacting step. Vapors from a first distillation (which serves to remove acids and part of the i-butane from the hydrocarbons) are condensed and separated into a hydrocarbon and an acid phase. The acid phase is recycled and the hydrocarbon phase is introduced into a second distillation wherein iso-butane is separated from alkylate.

U.S.P. 2,400,437. Hydrocarbon Conversion. M. M. Perkins and B. Sellmeyer to The M. W. Kellogg Company.

Unsaturated carbocyclic compounds are alkylated with olefins by passing a heated mixture of reactants over an elongated stationary bed of solid catalyst. The temperature in the reaction zone is controlled by introducing a cool liquefied hydrocarbon mixture comprising olefinic hydrocarbons into that section of the reactor first traversed by the heated mixture and by introducing cool liquefied unsaturated carbocyclic compounds into that portion of the reactor last traversed by the heated mixture.

POLYMERIZATION, CONVERSION

U.S.P. 2,398,759. Conversion of Fluid Hydrocarbons. C. H. Angell to Universal Oil Products Company.

In a catalytic process employing solid catalyst transported in a fluid manner through reaction and regeneration zones and in which the system is thermally unbalanced in that the exothermic heat evolved in the regeneration step is in excess of heat required in the reaction step, the catalyst is transferred from one zone to the other by means of a fluid low-boiling hydrocarbon. The hydrocarbon quantity and temperature is controlled to remove excess heat from the catalyst. The transportation fluid is removed from the catalyst prior to its entering the reaction or regeneration zone.

U.S.P. 2,398,908. Preparation of Aviation Gasoline from Normally Gaseous Hydrocarbons. P. Miller to Standard Catalytic Company.

Olefins in a butylene-butane cut are polymerized by a hot sulfuric acid catalyst. The polymer fraction is hydrogenated and fractionated into normally gaseous hydrocarbons consisting of isobutane and nbutane and a liquid isoparaffin fraction boiling predominantly above 225° F. Olefins in a C_3 to C_5 cut are alkylated with the ibutane fraction in the presence of a BF_3-water catalyst. Alkylate boiling mainly above 130° F. is combined with the liquid isoparaffin fraction boiling above 225° F.

U.S.P. 2,400,129. Solution Polymerization Process. J. F. Nelson and A. B. Small to Standard Oil Development Company.

A polymer having a molecular weight of 15,000-25,000 is obtained by dissolving in CS_2 which has been chilled to —10 to —150° C. a major proportion of

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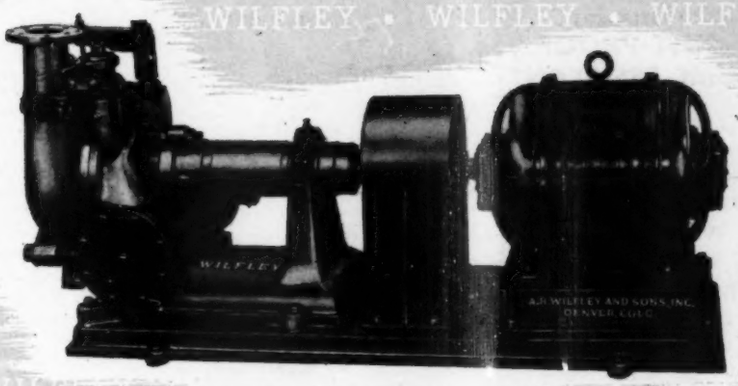

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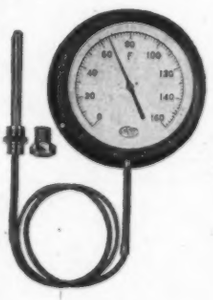

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isobutylene and a minor proportion of a conjugated diolefin of 4-12 C atoms, and polymerizing the hydrocarbons in solution by the addition of a Friedel-Crafts type catalyst.

U.S. Patent 2,400,176. Catalytic Conversion. E. W. Thiele to Standard Oil Company (Indiana).

A mixture of a catalyst material with at least 25 percent by volume of an inert, dense, non-combustible heat-retention material having about the same particle size as the catalyst, on which carbonaceous matter has been deposited, is heated in a regeneration zone by burning off the carbonaceous deposit. At least part of the heat is utilized for effecting endothermic conversion of hydrocarbons in the conversion zone. The mixture of catalyst and retention material with the carbonaceous matter again deposited thereon is removed from the conversion zone, stripped with steam, and returned to the regentration zone. The regeneration temperature is preferably 950-1050° F., the size of the catalyst and retention material is about ⅛-inch. Iron shot or smooth quartz particles may be used as the retention material.

HYDROGENATION DEHYDROGENATION AROMATIZATION

U.S.P. 2,399,751. Process for Producing Aromatics. W. J. Mattox to Universal Oil Products Company.

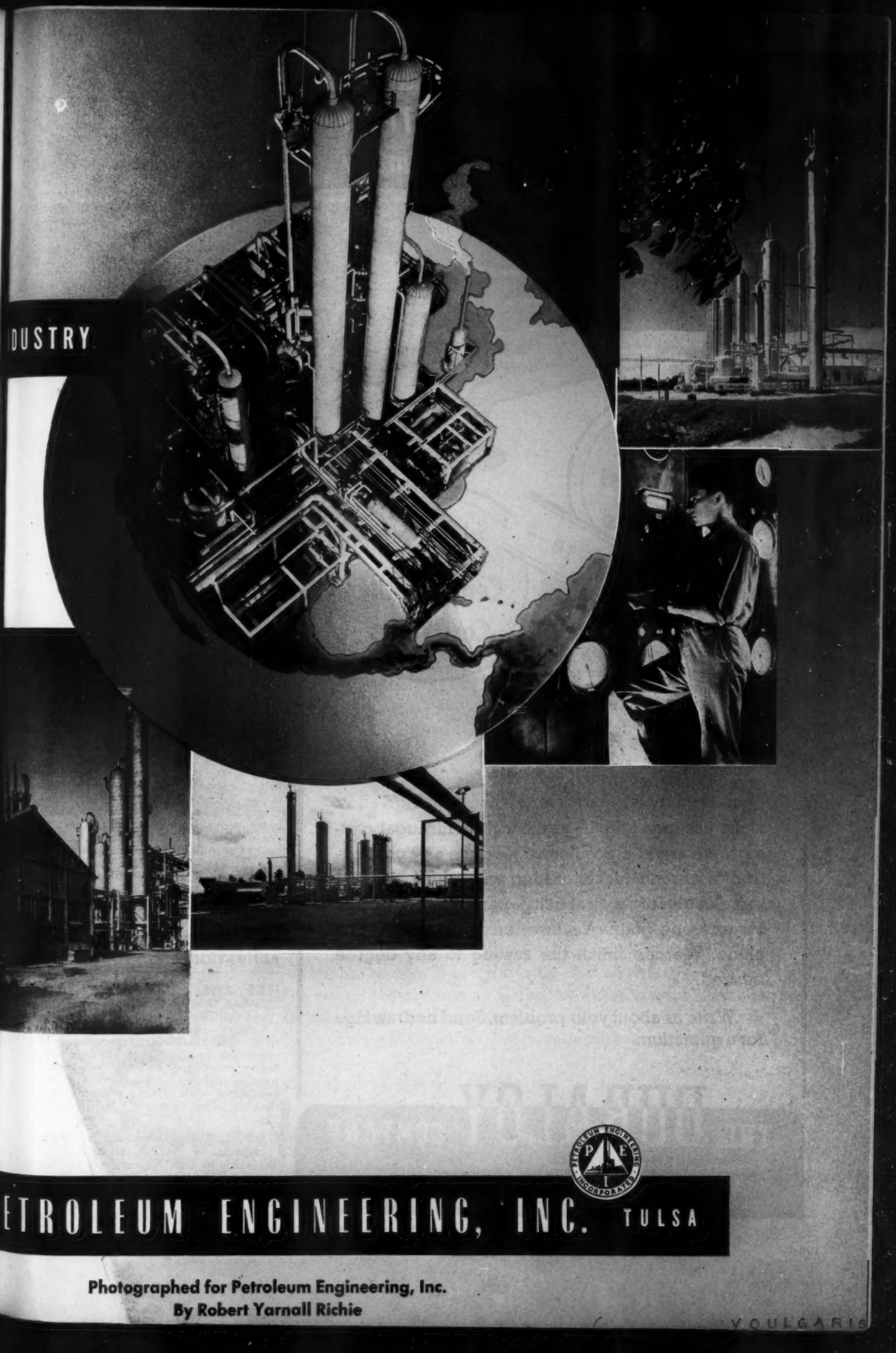
Aromatic hydrocarbons and high antiknock motor fuel of low bromine number are produced by cracking oil, separating a fraction boiling within the gasoline range from the cracked products and subjecting this fraction to dealenification either at 350-600° F. with a phosphoric acid catalyst or at 400-1000° F. with a silica-alumina catalyst, which may be a natural mineral. The product of the treatment is separated into a low-bromine-number gasoline fraction and a higher-boiling aromatic fraction which is recycled to the cracking step. The gasoline fraction is aromatized at 900-1100° F. with a catalyst comprising chromia or alumina associated with molybdena.

U.S.P. 2,399,780. Manufacture of Aromatic Hydrocarbons. G. B. Arnold to The Texas Company.

A mixture of benzene and petroleum naphtha containing aromatic hydrocarbons is converted with a silica-alumina catalyst at 800-1000° F. to effect an exchange reaction between benzene and higher-boiling homologues thereof. Lower-boiling fractions containing toluene are separated from higher-boiling fractions. The latter are cracked with a metal fluoride catalyst such as aluminum, magnesium or chromium fluoride at 900-1100° F. and 100-400 psi pressure to effect conversion to benzene which is charged to the first reaction zone.

U.S.P. 2,399,895. Dehydrogenation and Isomerization of Olefins. W. D. Seyfried and S. H. Hastings to Standard Oil Development Company.

A feed stock containing a C_4 paraffin and a C_4 mono-olefin is subjected to extraction to remove the paraffin. The product from the extraction step is contacted at 1150-1300° F. with a catalyst comprising approximately 80 percent MgO, 14 percent Fe_2O_3, 3 percent K_2O



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and 3 percent CuO for a sufficient time to allow formation of substantial amounts of C_4 diolefin and the isomerization of C_4 mono-olefin. Diolefin is removed from the product and at least a portion of the remainder is used as feed for the extraction step. Steam may be used to dilute the hydrocarbons.

U.S.P. 2,400,363. Production of Aromatics. H. H. Meier to Standard Oil Development Company.

The process involves production of toluene from a mixed feed of virgin and cracked naphthas of the proper boiling range in a hydroforming system. The feed stock is so adjusted that the ratio of naphtha to olefinic materials is not less than 1:1.

DESULFURIZATION

U.S.P. 2,398,919. Process for Catalytic Desulphurization. A. C. Byrns to Union Oil Company of California.

Sulfur-containing hydrocarbon oils are treated with hydrogen in the presence of complex catalysts. Even complex organic sulfur compounds are decomposed to hydrocarbons and hydrogen sulfide. The reaction is carried out at above 600° F. with a catalyst prepared by commingling an aqueous solution of a salt of iron, cobalt and nickel with an aqueous solution of a basic salt of chromium and molybdenum and adding ammonium hydroxide to the solution to precipitate a complex salt of metals of the two classes. Cobalt molybdate is a preferred catalyst and may be used dispersed on a carrier.

U.S.P. 2,399,496. Desulphurization Process. M. P. Matuszak and G. H. Morey to Phillips Petroleum Company.

Hydrocarbons containing organic sulfur compounds are desulfurized by admixing them with hydrogen and contacting the mixture at 300° C. and under 250 psi pressure with an unglowed chromium oxide catalyst. The catalyst, composed of coarse granules is prepared by subjecting an ammonium-containing salt of chromic acid to controlled heating in a free oxygen contianing atmosphere at a temperature 75° C. below spontaneous-decomposition temperature. An unglowed dark residue with a content of chromium having a valence higher than 3 within a range of 25-40 percent of the total chromium is obtained. The decomposed salt is subjected to a reducing atmosphere at 175-250° C.

CATALYST PREPARATION ACTIVATION AND REGENERATION

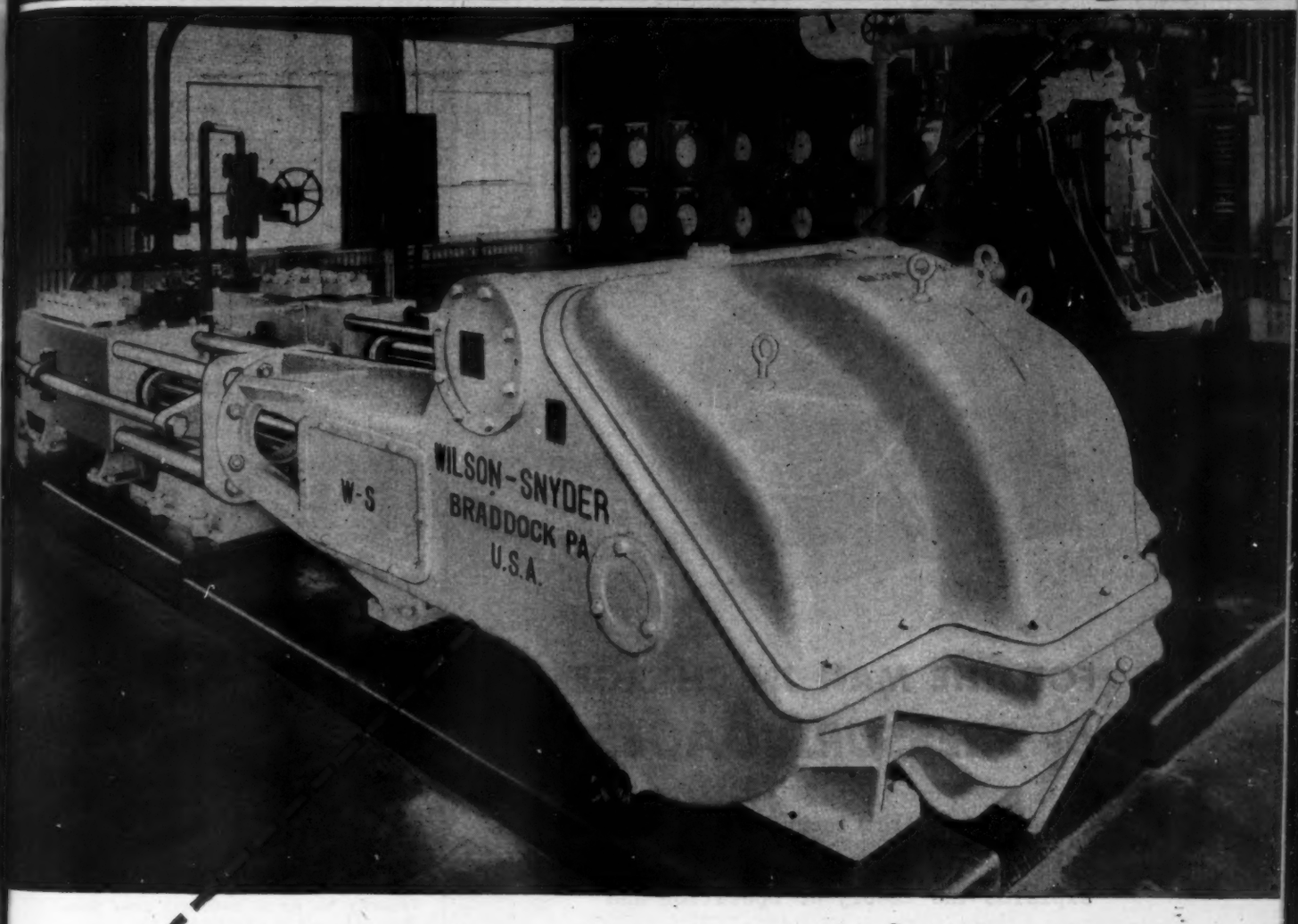
U.S.P. 2,398,773. Conversion of Hydrocarbon Oils. G. C. Connolly to Standard Oil Development Company.

Catalyst having a high order of activity for cracking hydrocarbons and consisting principally of alumina and a boron compound may be prepared by treating alumina or an alumina forming compound with BF_3 or complex boron fluoride salts such as NH_4BF_4 or the like.

U.S.P. 2,399,093. Conversion of Hydrocarbons. W. S. Bonnell and W. W. Weinrich to Gulf Research & Development Company.

Catalysts of the Friedel-Crafts type which have been utilized to promote alkylation reactions to a point where

WILSON-SNYDER *Power Pumps*



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their activity for this purpose is exhausted, are still capable of promoting catalytic isomerization reactions. They are used to start the isomerization of pparaffin hydrocarbons at 80-150° C. The isomerization reaction is completed with fresh aluminum halide catalyst at the same temperature.

U.S.P. 2,399,678. Catalysis. E. J. Houdry and H. A. Shabaker to Houdry Process Corporation.

Dehydrogenation catalysts for the production of butadiene with high yields and little coke formation are described. The catalysts which contain a minor portion of chromium oxide and a major portion of surface-active alumina are preconditioned by contact with steam at 1200-1600° F. at a partial steam pressure of between 1 and 30 psi.

U.S.P. 2,400,020. Catalytic Cracking of Hydrocarbon Oils. J. A. Pierce and C. T. Steele to Standard Oil Development Company.

Bentonite-type clays are activated by treatment with at least 20 percent of oxalic acid, followed by treatment with sulfuric acid. Treating temperatures of 175-210° F. are employed. Excellent cracking catalysts result.

U.S.P. 2,400,025. Treatment of Catalyst. W. G. Scharmann to Standard Oil Development Company.

High compression strength is imparted to a catalyst containing alumina and a compound of a metal of the VI group of the periodic system, the original compression strength of which has been reduced by prolonged exposure to air during storage, by heating the catalyst to a temperature of 500-1200° F. for a period of one hour.

U.S.P. 2,400,465. Catalytic Conversion of Hydrocarbons. M. M. Marisic to Socony-Vacuum Oil Company.

A catalyst for converitng hydrocarbons is prepared by forming a homogeneous colloidal solution with a pH of 2.5 to 10 by mixing an alkali metal silicate solution with an acid solution. One of the aqueous solutions contains a soluble zirconium compound. The colloidal solution formed has an inherent capacity to set a hydrogel after some time. The sol is admitted in the form of separate globules to a body of oil where the globules assume spheroidal shape of not more than 2.5 mm. diameter. Once formed, the hydrogel retains this shape. The hydrogel spheroids are treated to remove alkali metals therefrom by base exchange.

REFINING

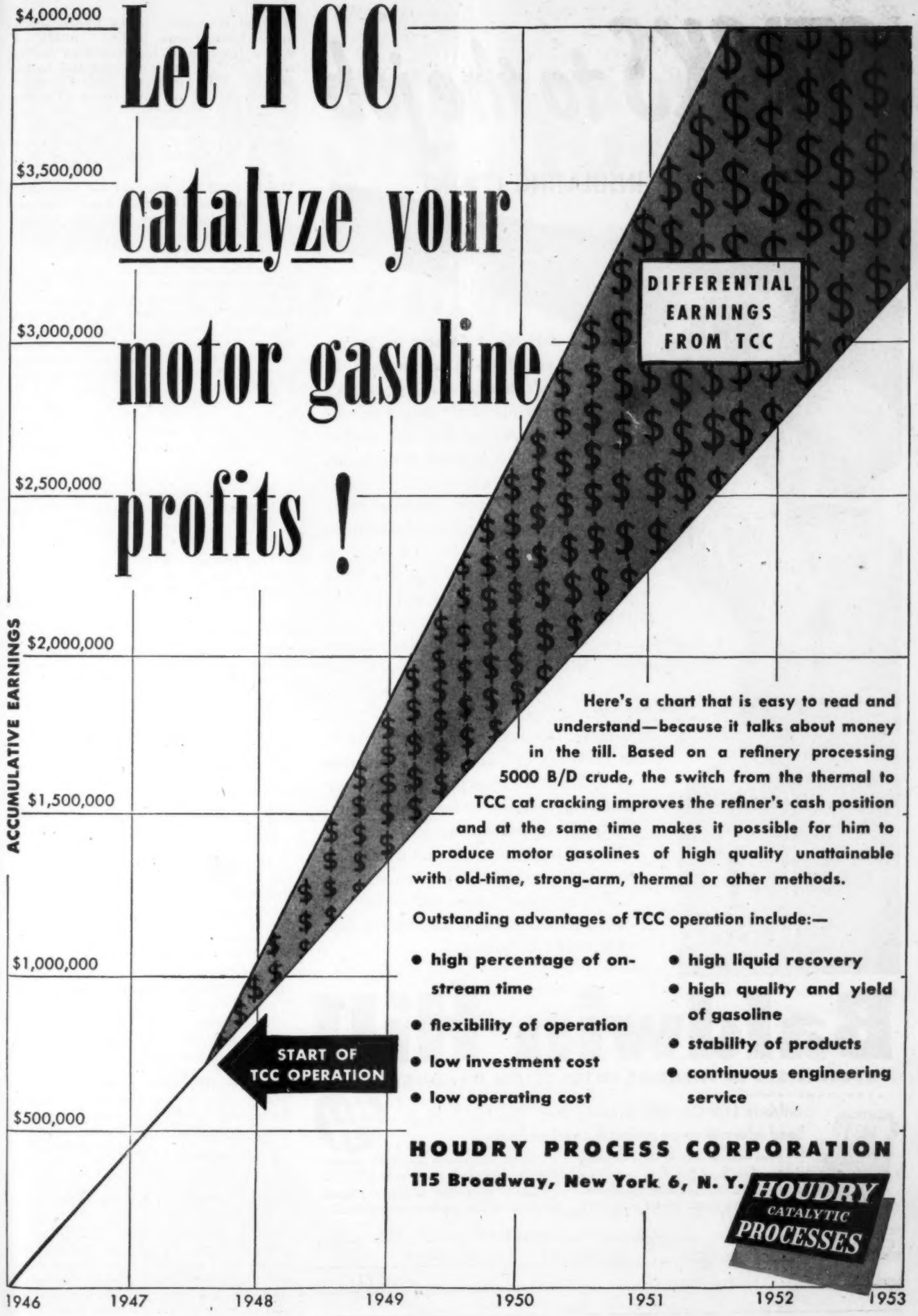
U.S.P. 2,398,810. Chemical Process. F. J. Soday to United Gas Improvement Company.

Butadiene or other diolefins containing acetylenic impurities are purified by passage in the vapor phase at below 100° C. through a dispersion containing finely divided sodium. The dispersion is at least 1 foot thick in the direction of flow, contains less than 30 percent by weight of sodium. The diolefin concentration in the zone is less than 80 percent of the total material present.

U.S.P. 2,398,846. Making Gasoline. J. C. Munday to Standard Oil Development Company.

Products from the catalytic cracking of a gasoil are fractionally distilled. A

Let TCC catalyze your motor gasoline profits!



Here's a chart that is easy to read and understand—because it talks about money in the till. Based on a refinery processing 5000 B/D crude, the switch from the thermal to TCC cat cracking improves the refiner's cash position and at the same time makes it possible for him to produce motor gasolines of high quality unattainable with old-time, strong-arm, thermal or other methods.

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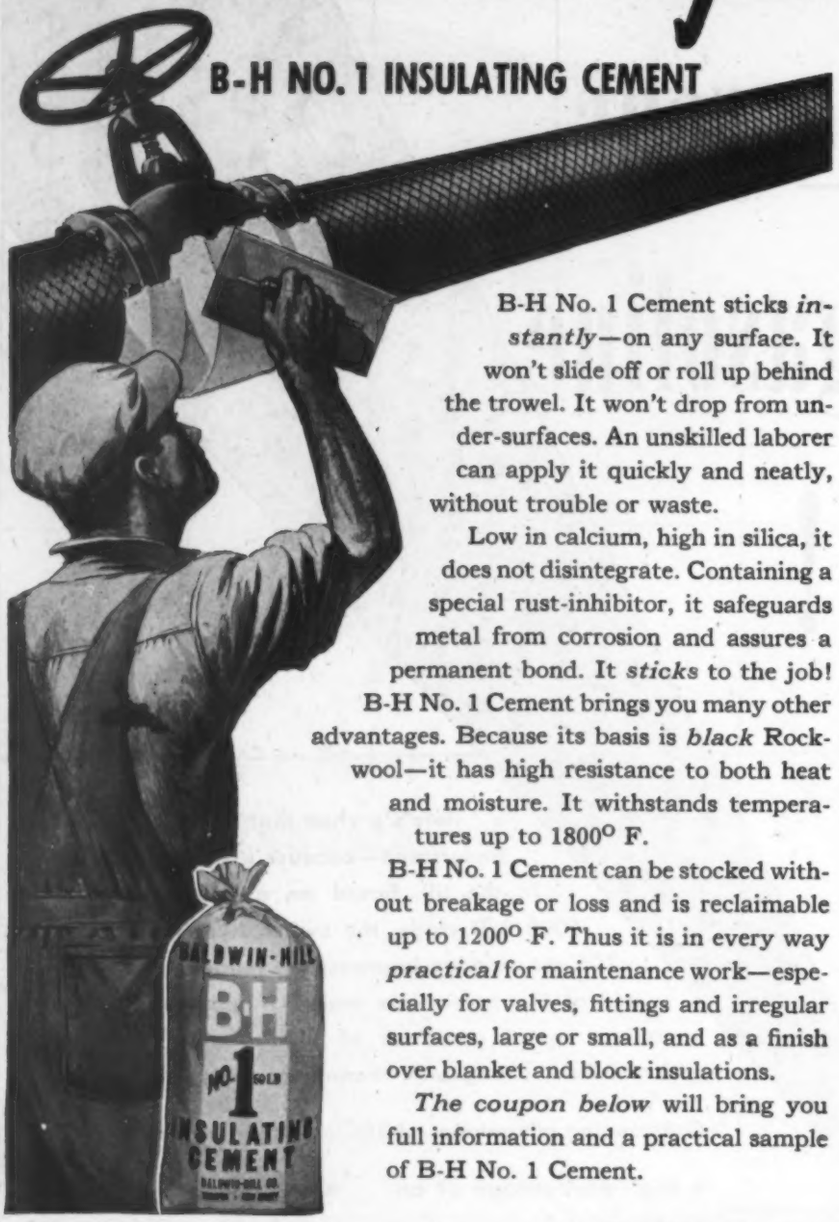

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fraction consisting of C_5 hydrocarbons and hydrocarbons boiling to 325° F. and a fraction of hydrocarbons boiling above 500° F. are combined and hydrogenated, saturating olefins and converting aromatics to naphthenes. The hydrogenated products are distilled, aviation gasoline boiling up to 325° F. is recovered and a fraction boiling above 500° F. is recycled to the cracking zone.

U.S.P. 2,398,930. Process for Separating Monomeric Diolefins from Mixtures of Relatively Low Boiling Diolefin and Mono-olefin Monomers. W. W. Gary to Filtrol Corporation.

Butadiene is separated from mixtures of butadiene and more saturated hydrocarbons by catalytically polymerizing butadiene into polymers of higher boiling point than the charge stock. The polymer is separated and depolymerized and part of the resulting pure butadiene is recycled to the polymerization stage. Polymerization at 350-550° F. and depolymerization at 800-900° F. are carried out with the same catalyst, consisting of an acid-treated montmorillonite clay containing 15-20 percent Al_2O_3.

U.S.P. 2,399,224. Conversion of Hydrocarbons. V. Haensel and V. N. Ipatieff to Universal Oil Products Company.

The bromine number of an unsaturated cracked gasoline is reduced by separating the gasoline into a light and a heavy fraction, subjecting the light fraction to contact with a phosphoric acid catalyst at 400-550° F. under sufficient pressure to maintain at least part of the hydrocarbons in liquid phase and subjecting the heavy fraction to contact with a silica-alumina or silica-zirconia catalyst at 480-700°F. under sufficient pressure to maintain at least part of the hydrocarbons in liquid phase. Fractions boiling within the desired range are separated from the products and blended.

U.S.P. 2,399,261. Production of Aviation Fuel. C. L. Thomas to Universal Oil Products Company.

The olefin content of an olefinic gasoline is reduced by contacting the gasoline with a catalyst comprising an association of silica and magnesia at 650-1050° F. to produce a liquid product which has an olefin content less than half that of the charge stock.

U.S.P. 2,399,340. Distillation of Aromatic Olefins. R. A. Franz to The United Gas Improvement Company.

In the distillation of a heat polymerizable aromatic olefin the improvement is claimed which comprises distilling the aromatic olefin in the presence of oxygen and in the presence of a polymerization inhibitor selected from the group consisting of inhibitors containing a phenol group, a quinone group or an amine group.

U.S.P. 2,399,413. Aviation Gasoline. F. T. Weiss and C. E. Arbuthnot to Shell Development Company.

Hydrindene (cyclotrimethylene benzene) is an aromatic hydrocarbon which has the property of greatly increasing the rich mixture response of paraffin and/or naphthenic aviation base stocks

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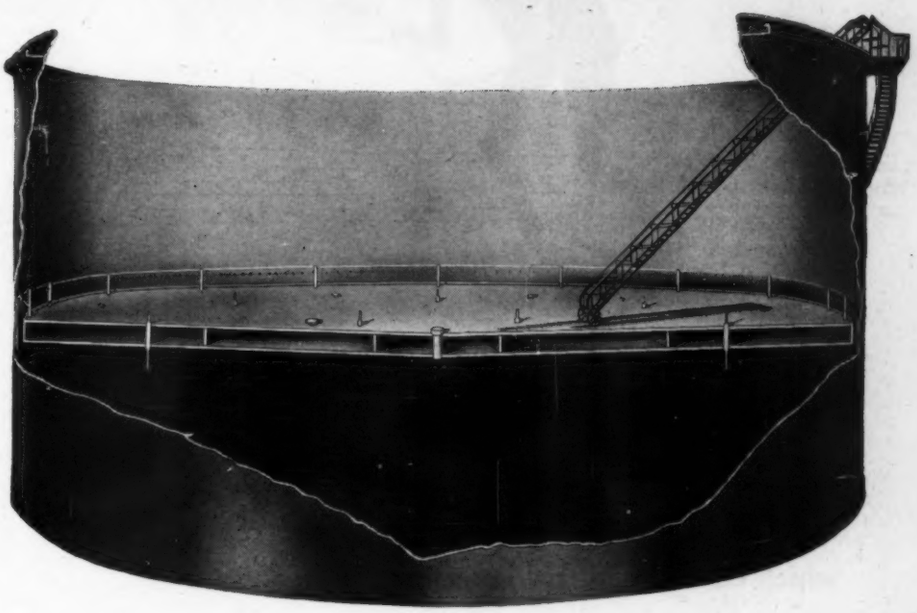
The GRAVER PONTOON FLOATING ROOF

An improved double deck floating roof of simplified construction with positive vapor pressure seal.



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- **For finished products in tanks too isolated for practical manifolding or in tanks where excessive differences in filling and withdrawal may exist, such as a water terminal.**
- **For "sour" crudes. The roof lies entirely upon the surface of the liquid and eliminates any vapor space and the possibility of corrosion.**

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1. **Double Deck insulates stored liquid against boiling.**
2. **Vapor tight seal is doubly actuated by springs *plus vapor pressure.***
3. **Secondary seal provided if desired.**
4. **Smooth deck—no pockets for accumulation of dirt or water.**
5. **Screened open drain. Pipe drain optional.**
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7. **Seal composed of 16 gauge heavily galvanized or stainless steel continuous shoe and long lasting synthetically treated fabric.**
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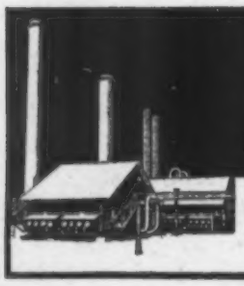

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to which it is added in amounts of from 1 to 15 percent.

U.S.P. 2,399,514. Process for Decolorizing Light Oil Fractions by Selective Hydrogenation. E. H. Smoker to The United Gas Improvement Company.

A colored light oil styrene fraction contaminated with color imparting material (such as up to 8 percent of phenylacetylene) is vaporized and hydrogenated over a nickel catalyst at 150-160° C. and under a pressure of 40 mm. Hg. Condensed products are colorless and contain substantially all of the styrene and no phenyl acetylene.

U.S.P. 2,399,882. Olefin Concentration. C. E. Morrell, J. K. Small and J. H. McAteer to Standard Oil Development Company.

A mixture of hydrocarbon containing acetylenes and diolefins is treated with a cuprous salt solution. The cuprous salt solution containing acetylenes and diolefins dissolved therein is heated to separate pure diolefin and to form polymers. The polymer-containing solution is treated with an adsorptive solid material to remove the polymers.

U.S.P. 2,400,340. Process for Separating Olefins from a Hydrocarbon Stream. J. H. Cone to Standard Oil Development Company.

Olefins are removed from a feed stock containing predominantly C_4 hydrocarbons by extration with sulfuric acid of about 65 percent concentration. The extract is washed with 1-20 volume-percent of naphthenic acid to remove foaming agents therefrom and is then heated under reduced pressure to vaporize a major portion of the hydrocarbons.

U.S.P. 2,400,350. Separation of Olefins. I. D. Hall to Standard Oil Development Company.

Normal butylenes of a purity of 97 percent are recovered in yields of better than 90 percent from mixtures thereof with C_4 hydrocarbons by a hot acid copolymerization of iso- and normal-butylenes, followed by catalytic cracking of the resulting copolymer and by cold acid absorption separation of isobutylene from the n-butylenes.

U.S.P. 2,400,355. Production of Aromatics. M. C. K. Jones and F. W. Schumacher to Standard Oil Development Company.

The invention is concerned with the recovery of toluene from hydrocarbons containing toluene in the presence of olefins. The hydrocarbon mixture is fractionated into narrow-boiling fractions and is then clay treated in order to remove the olefins by polymerization. The clay-treated product is fractionated to a cut boiling in the range of 175-265° C. which is subjected to a second clay treatment at higher temperature, polymerizing further quantities of olefins. The polymer-free product is extracted with phenol.

U.S.P. 2,400,373. Refining Hydrocarbon Oil. H. G. Schutze to Standard Oil Development Company.

A nitration grade of toluene is recovered from a fraction comprising toluene and olefins by acid treating the mixture at 80 ° F. in two stages using fresh acid in the second, acid sludge from the second in the first stage. The acid-treated oil is neutralized with a concentrated aqueous solution of caustic soda, separated from the solution, heated

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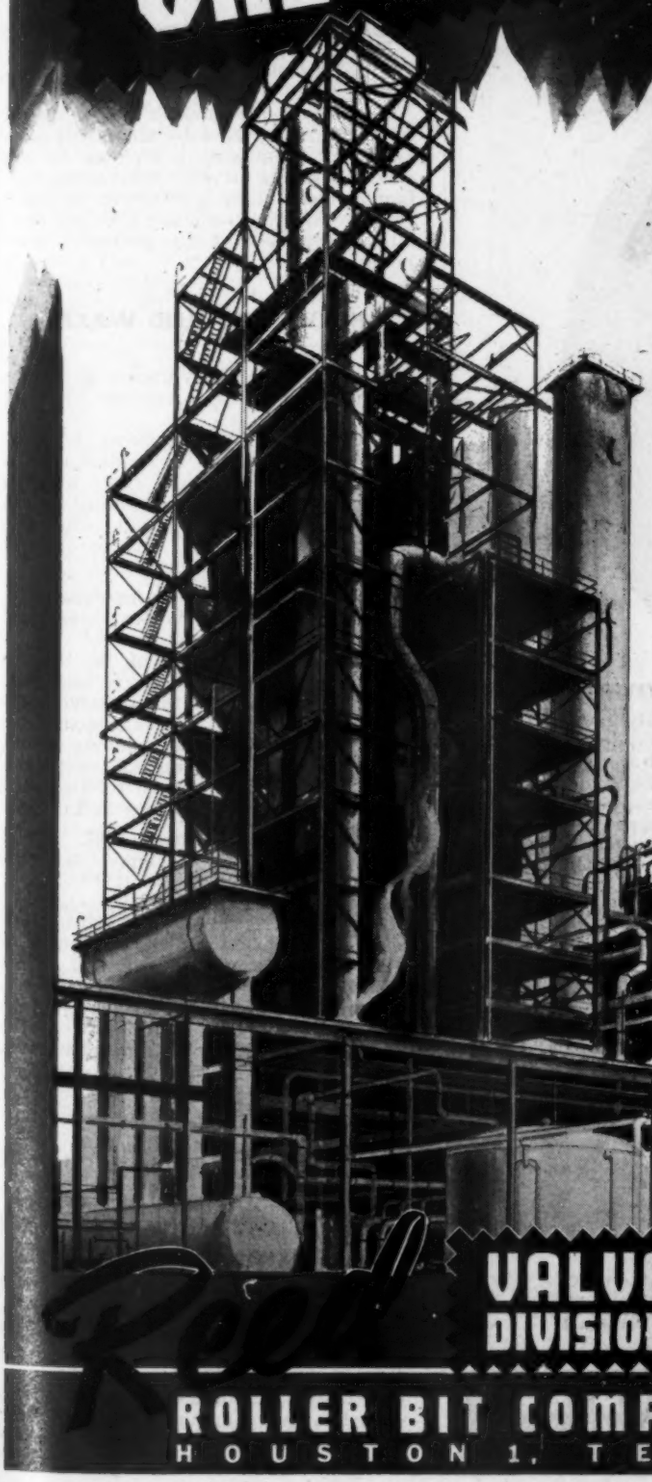

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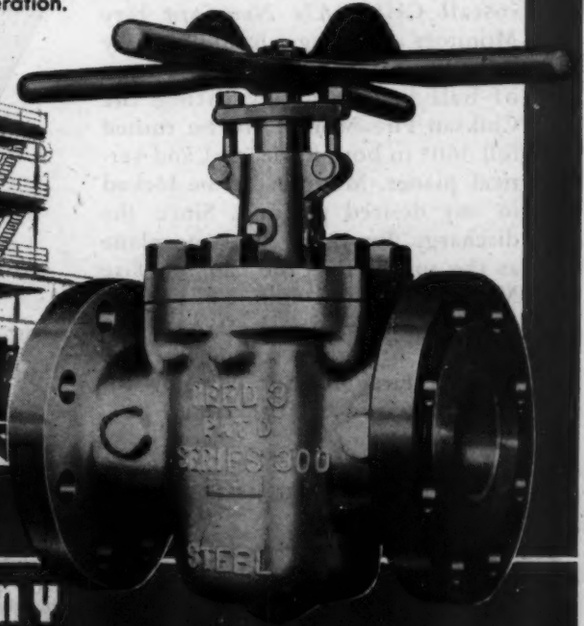

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to 300-325° F., admixed with caustic alkali having a gravity of 18-24° Bé, maintained in contact for at least 10 minutes and separated from the hot solution. The oil is then redistilled.

U.S.P. 2,400,376. Process for Recovering Olefins from a Hydrocarbon Stream. J. C. Showalter to Standard Oil Development Company.

Olefins are removed from a C_4 hydrocarbon feed stock by sulfuric acid extraction. They are recovered by heating the extract under reduced pressure. In order to eliminate foaming in the recovery step, oil-soluble sulfonic acids are added to the extract in an amount of 0.005 parts per million.

U.S.P. 2,400,394. Process for Breaking Petroleum Emulsions. M. de Groote and B. Keiser to Petrolite Corporation, Ltd.

Petroleum emulsions of the water-in-oil type are resolved by treatment with an agent comprising a member of the class consisting of (A) substituted carbamyl compounds containing at least two glyoxalidine radicals; (B) oxyalkylated derivatives of the carbamyl compounds.

HEAVY OILS AND WAXES

U.S.P. 2,399,192. Dehydration of Transformer Oils. P. P. Alexander to Metal Hydrides, Inc.

Transformer oil containing a small amount of moisture is treated with a suitable metal hydride (e.g. alkaline earth metal hydride), employed in an amount sufficient to react with the moisture present. No objectionable breakdown of the oil occurs.

U.S.P. 2,399,521. Wax Composition. W. S. Tyler to Tide Water Associated Oil Company.

The tensile strength of an oil-free crystalline petroleum wax is increased by the incorporation of a solvent-deoiled, substantially oil-free paraffinic amorphous wax. The amorphous wax is prepared from conventional centrifuge wax from which the usual 6-10 percent residual oils have been removed.

U.S.P. 2,399,817. Mineral Oil. R. E. Meyer to Socony-Vacuum Oil Company.

Agents which impart substantial improvement in viscosity to lubricating-oil fractions when added in amounts of 0.1 to 5 percent are described. They consist of oil-soluble, neutral copolymers obtained by reacting diolefins with carbonyl compounds selected from the group consisting of unsaturated ketones and aldehydes in the presence of metal halide catalysts (e.g. $AlCl_3$, BF_3, $SnCL_4$) at temperatures from —40 to 25° C.

U.S.P. 2,400,298. Method of Acid Treating a Viscous Hydrocarbon Oil. B. G. Jones and L. H. Sharp to Tide Water Associated Oil Company.

A viscous hydrocarbon oil is treated with sulfuric acid under conditions to convert unstable oil constitutents to oil-soluble sulphonation products. The oil is centrifuged to remove acid sludge and is then stored for 10-60 minutes without further treatment to cause unstable oil-soluble bodies to polymerize to insoluble compounds. These are separated by centrifuging and soluble acidic bodies then are removed by treatment with alkyli.

NEW EQUIPMENT

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1—Dewpoint Recorder

General Electric Company, Schenectady, New York, has announced a dewpoint recorder which can determine automatically the amount of moisture in a gas. The instrument is designed for applications where the moisture content of atmospheres and gases must be measured or controlled, such as in checking furnace atmospheres, testing city gas, or determining the humidity of gases used in factory production processes.

The new dewpoint recorder is a combination of heater, refrigerator, mirror and gas chamber. The test gas enters the gas chamber and comes in contact with a metal mirror. The refrigerator and heater cool or heat the mirror until a temperature is attained at which moisture in the gas forms dew on the mirror. A photoelectric eye watches the mirror, and the mirror temperature is recorded on a graph or chart the moment dew forms. Working in co-ordination, the refrigerator and heater hold this dewpoint temperature within a tolerance of two degrees so that a continuous reading on the chart is achieved. The dewpoint temperature that is recorded can then be converted into the moisture content of the gas if desired. The recorder can be arranged so that it will flash or sound a warning when moisture in the gas reached too high or too low a level, or control other equipment which will dehumidify or add moisture to the gas.

The new instrument is designed for operation at atmospheric pressure over a dewpoint range from ambient to —90 F. After initial installation, only minor adjustments are required for continuous operation.

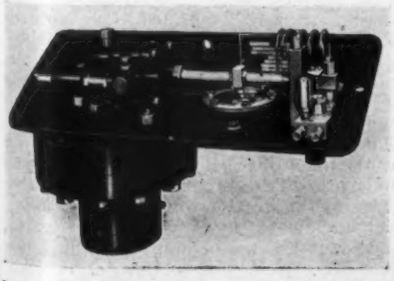
CHECK THE CARD AT PAGE 233

2—Hot-Liquid Meter

Republic Flow Meters Company, 2240 Diversey Parkway, Chicago 47, is in production with a pneumatic transmitter designed for measuring flow of hot liquids which would congeal at normal temperature. A piston is used instead of the ordinary diaphragm to avoid the effect of the hot liquid on diaphragms.

The transmitter is designed for installation in a manner that keeps the measuring chambers hot enough to prevent the measured fluid from congealing in the transmitter chambers and lead lines. The piston and cylinders are made of steel of the same composition so that clearance is maintained regardless of temperature changes.

Literature is available.



Republic Differential Transmitter for Measuring Hot Liquids

G-E Dewpoint Recorder

CHECK THE CARD AT PAGE 233

3—Thread Sealing Compound

Rector Well Equipment Company, Fort Worth, Texas, announces "Rector-Seal No. 15," a thread lubricant and seal on oxygen lines and fittings. Developed during the war and used on breathing lines in aircraft, it only recently has been made commercially available. The compound does not react with oxygen and thus makes possible a safe leak-proof screwed connection that can be changed readily without damage to threads or fittings. Used also as a stem lubricant on oxygen valves. Data sheet giving detailed physical characteristics is available upon request.

CHECK THE CARD AT PAGE 233

4—Meter

Askania Regulator Company, 1603 S. Michigan Avenue, Chicago, has introduced the "Transometer," designed primarily for control, integrating, remote indicating and recording of heavy fuel oil in the combustion field, but applicable to any viscous fluid.

Full details are given in Bulletin 111.

CHECK THE CARD AT PAGE 233

5—Meter Body

The Brown Instrument Company, 4498 Wayne Ayenue, Philadelphia 44, is introducing a new electric meter body with sealed armature, eliminating external seals and obtaining better measurement of high-viscosity fluids and gassing liquids. The new meter body was developed, it was said, to meet specific requirements of the petroleum and chemical industries, particularly for measuring flow of viscous liquids that are heated to permit pumping, or heated as a step in the process to which liquids are subjected. An announcement, following tests in several petroleum and chemical processes, said:

"Satisfactory operation is obtained when measuring fluids that are highly viscous at normal temperatures. Meter response is improved and, when fluid is placed directly in the meter body, neither seal pots nor liquid purging are required. The meter is essentially self-venting, high pressure connections being centrally located above the float chamber. The new armature assembly is sealed, protected and lubricated by a mercury fill, being repositioned by smaller variations in differential pressure.

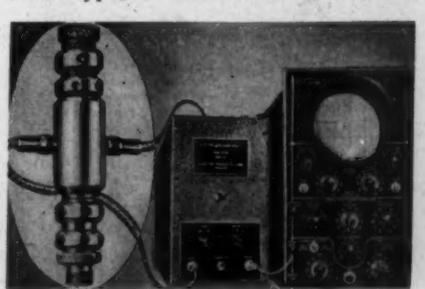
"In addition to its suitability for high viscosity measurement the new meter body can successfully measure hydrofluoric acid, mixtures of hydrofluoric acid and hydrocarbons, and volatile fluids with other characteristics. Suitable applications include tar and pitch, tower bottoms, bunker 'C' fuel oil, volatiles such as butane and propane, steam, water, gases and hydrofluoric alkylation processes."

CHECK THE CARD AT PAGE 233

6—Pressuregraph

Electro Products Laboratories, 349 West Randolph Street, Chicago 6, has announced important improvements in a new model of its "Pressuregraph.

The new instrument provides, with a cathode ray oscillograph, a substantially linear pressure-time curve on the screen, which indicates the performance of any engine, pump, or other device subject to pressure variations. It is used for studies of all types of internal-combustion en-



Pressuregraph

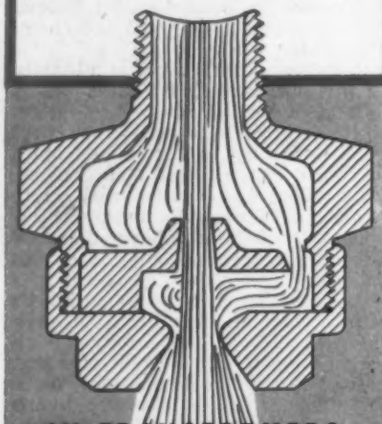
Listed by Underwriters Laboratories, Inc.

This is how the

BLAW-KNOX

Aquatomic

FOG NOZZLE FIGHTS FIRE



IN TRANSFORMERS, FLAMMABLE LIQUIDS AND STORAGE TANKS

The *Aquatomic Fog Nozzle* creates a cone of atomized water particles having force enough to reach to the base of the fire in spite of air turbulence and drafts.

At the same time, these particles are fine enough to give a maximum cooling and quenching effect, and are so well separated as to prevent conduction of electric currents.

The spray pattern is maintained even with reduced pressures. Clear passages in the nozzle prevent clogging.

Also—

Standard Wet and Dry Pipe Systems, as well as Thermostatically Controlled Pre-Action and Deluge Systems.

Write for details

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SPRINKLER DIVISION

832 Beaver Avenue, N. S.,

Pittsburgh 12, Penna.

gines, pumps, compressors, air and liquid pipe lines, etc. It is used for diesels, for C.F.R. aviation-fuel test engines, 2-cycle engines, and a wide range of other applications. In addition to dynamic pressure variations, it shows static or slow pressure variations. It covers all mechanical speeds, and pressures up to 10,000 psi. There is no appreciable inertia to overcome in the electronic driving mechanism.

The new Pressuregraph provides means for temperature compensation. There are three output selections: for double modulated wave; for indicator card wave; and integrated single line providing means for transmission of pick-up response to a string oscillograph, for photographic recording. The pick-up has been re-designed, made vibration-proof, and is furnished with or without water-cooling.

Operation is simple. There is only one control. The pick-up is inserted in cylinder, chamber of airline, etc. The pick-up includes a diaphragm which, when acted on by pressure impulse, unbalances an electronic circuit. The unbalanced voltage from the pick-up is delivered to the cabinet where it is amplified, and passed through a negative modulation suppressor, and then to the oscillograph. The sweep circuit of the oscillograph is adjusted to the speed of the engine or mechanism under test. A band of light appears on the screen, the contour or shape of which light is the true pressure-time curve. This band of light is not a line or tracing, but an area similar to that of a television picture, and easily readable.

CHECK THE CARD AT PAGE 233

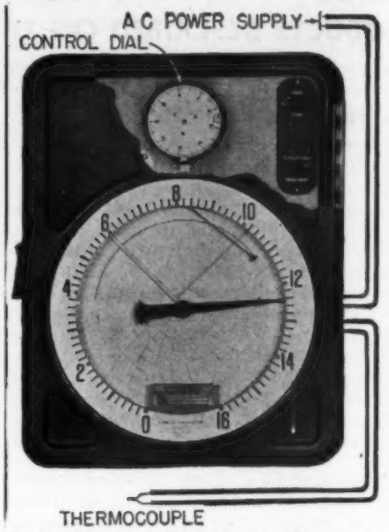
7—Potentiometer-Pyrometer

Bailey Meter Company, 1050 Ivanhoe Road, Cleveland 10, Ohio, has announced an electronic potentiometer-pyrometer which has no continuously moving or vibrating parts in the measuring circuit. It records one or two temperatures on a 12-inch chart and indicates on a 29-inch bold scale which encircles the recording chart. A 115-volt, 60- or 50-cycle, a-c power supply is required. The instrument operates from a thermocouple or from any source of d-c potential which varies through at least 10 millivolts for full scale range. Conventional thermocouples are used for temperatures up to 3000° F. For temperatures above 3000° F. and for moving objects above 1500° F., radiation-type thermocouples are used.

The d-c potential of the thermocouple or other primary element is balanced against a conventional potentiometer circuit employing the usual battery source of d-c voltage and a standard cell with manual standardization. Instead of a galvanometer or millivoltmeter the Bailey pyrotron potentiometer circuit employs a d-c to a-c converter and an electronic detector, to measure potentiometer unbalance.

Galvanometers, millivoltmeters and all continuously moving or vibrating mechanism are not used in the measuring system. Only the recording chart moves continuously. The reversible electric motor which drives the indicating, recording, and controlling features moves only when the potentiometer network tends to become unbalanced because of a change in the factor being measured. Conversion of d-c potential to a-c is accomplished by reactors which are similar in construction to transformers in that they contain no moving or vibrating parts.

This instrument is said to be an effective controller for temperature since its inertia-free electronic detection and high-speed-motor system instantly respond to keep the measuring circuit in continuous balance. Its accuracy, stability and permanence of calibration are credited to the use of the null balance principle.



Bailey Electronic Potentiometer-Pyrometer

Bailey Pyrotron Recorder-Controllers are furnished for air-operated control systems, on-off electric control systems and throttling type electronic control systems. The instrument illustrated is cut away to show its control dial by which the set point may be manually adjusted to any desired temperature. This arrangement is used for the on-off electric and throttling electronic type controls. Air-operated control systems are provided with an indicating pointer which uses the recording chart as a scale for indication of the set point. The set point may be changed by turning a knob.

A 16-page Bulletin No. 232 describes and illustrates various indicating, recording and controlling combinations, gives performance data, and outlines principle of operation.

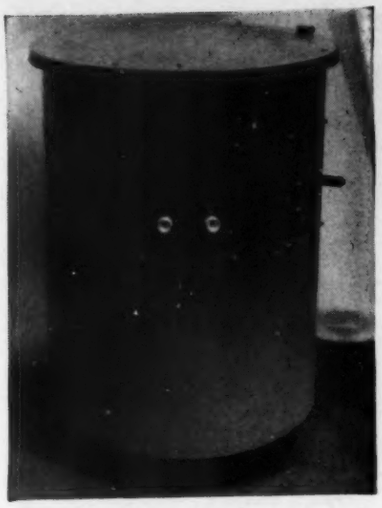
CHECK THE CARD AT PAGE 233

8—Brazing Unit

Westinghouse Electric Corporation, Box 868, Pittsburgh 30, has announced a new portable 10-kva brazer for general brazing service in joining copper or copper-alloy parts which may be brought together between brazing tongs.

The new single-phase, 60-cycle unit weighs 100 pounds, is provided with caster-type wheels and convenient handles for moving or carrying any place in the shop or yard. It requires only connection to a 220- or 440-volt source. Alternating current from an adjustable-voltage transformer passes through the tongs and parts to be brazed.

The transformer with line contactor is enclosed in a sheet-metal case, and a clamp-type entrance bushing is provided for the incoming primary cable. Built into the front of the brazer, the control panel contains outlets for brazing-tong cables, receptacle for foot-switch pilot cable, and voltage tap changing plug. The two-pronged plug-in switch quickly changes brazing voltage to 12, 10 or 8 volts. A switch for energizing the con-



Westinghouse Brazing Unit

tactor-control circuit is also provided on the control panel. Cooling of the unit is effected by natural air draft which enters at the bottom, passes over the brazing transformer, and is expelled through louvered openings at the top.

CHECK THE CARD AT PAGE 233

9—Ion Gauge

General Electric Company, Apparatus Department, Schenectady, New York, has announced a new ion gauge able to measure or monitor continuously the highest vacuums ordinarily encountered in factory or laboratory processes. Consisting essentially of a control unit and an ion gauge tube, the equipment measures pressures as low as 10-7 mm of mercury and reads directly in millimeters of mercury.

The continuous pressure-indication feature permits detection of small pressure changes and measurement of slow pressure drifts without the inconvenience of continual adjustments. A protective circuit is provided in the control unit to turn off the gauge-tube filament automatically at pressures above 10-4 mm. The control regulates filament emission against line voltage and pressure changes, assuring stable and accurate operation.

The ion gauge control unit includes the emission regulator circuit, a stabilized voltage supply, an electronic microammeter with indicating instrument, and the filament protective relay. The front panel contains all controls necessary for operation of the ion gauge. The gauge tube is a special glass triode with a tubulation for connecting to the vacuum system.

In operation, the gauge tube is sealed to the high-vacuum system and the tube is connected electrically to the control unit. Once preliminary adjustments have been made by use of the panel-mounted switches and controls, only infrequent adjustments are required over periods of several hours.

CHECK THE CARD AT PAGE 233

10—Return Bends

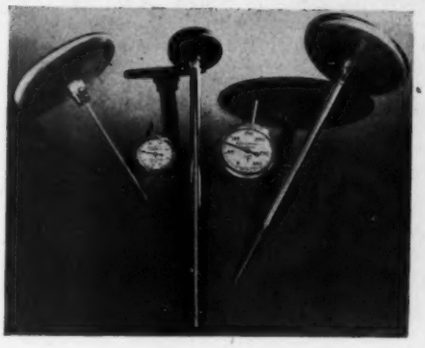
The Ohio Steel Foundry Company, Springleld, Ohio, recently has issued a bulletin on its Type 1000 return bend, which explains "directional solidification," a process newly adapted to manufacture of this item. A table shows dimensions and weights, and a tabulation gives information on materials, pressures and temperatures.

CHECK THE CARD AT PAGE 233

11—Dial Thermometer

Equipoise Controls, Inc., 100 Stevens Avenue, Mt. Vernon, New York, is manufacturing a dial thermometer that contains a bimetallic helical coil measuring element which is permanently calibrated and extremely responsive. It has a stainless-steel case and stem, large, easy-to-read numerals and temperature gradations on the metal dial. Unbreakable crystal glass can be furnished.

The expansion of a bimetallic coil rotates a small attached shaft and indicating pointer and forms the only moving part in the thermometer. There are no pivots, mechanical linkages or gears. Rugged construction protects the thermometer against vibration and shock. Standard ranges are available between —90° F. and 1000° F. Laboratory thermometers are graduated in both Centigrade and Fahrenheit. An over-range protection is built in the instrument and permits the temperature to be increased 50 percent or more beyond the end of the scale range without damage to the thermometer for ranges up to 500° F. Thermometers are available in 2-, 3- and 6-inch dial sizes.



Equipoise Thermometer

CHECK THE CARD AT PAGE 233

12—Bottle Carrier

Benson & Associates, 332 S. Michigan Avenue, Chicago, has introduced a cushioned, shock-resisting bottle carrier especially designed to minimize bottle breakage when handling and transporting hazardous chemicals. It is impervious to broken glass and prevents leakage of chemicals in case the bottle breaks. Two sizes are in production—for one-gallon jug and two-liter bottle—and can be designed for any size bottle.

CHECK THE CARD AT PAGE 233

13—Thermal Gas Analyzer

General Electric Company, Schenectady, New York, has announced a thermal gas analyzer, Type TB, for continuously recording or indicating the concentration of one component of mixed gases whose characteristics can be detected by the thermal-conductivity principle. The instrument can be used over a wide range of gases and gas concentrations. It can detect impurities in hydrogen, carbon dioxide, sulphur dioxide, or any one of many organic vapors, provided the impurity has a different thermal-conductivity from that of the gas being analyzed.

In order to adapt the analyzer to varied applications, a different reference gas can be obtained for each application. A change of the instrument scale and a new cell block, which contains the reference gas, permits an analyzer designed for one atmosphere to be applied to one that is radically different.

G-E Thermal Gas Analyzer

Gas analysis is registered on any standard indicating or recording instrument, which can be equipped with contacts for closing an alarm circuit when the concentration reaches a preset maximum or minimum value. In addition, these contacts can be used to control circuits for valves or motors in order to maintain the gas concentration within certain limits.

The new instrument features high sensitivity, rapid response to gas changes, and sealed-in reference gas for reliable operation. The cell clock is thermostatically controlled to prevent temperature errors. The analyzer is mounted in a cabinet or panel and is designed for permanent installation.

CHECK THE CARD AT PAGE 233

14—Floating Roof

Graver Tank & Manufacturing Company, East Chicago, Indiana, has announced a new floating roof for use on storage and filling tanks. The maker says the Graver Pontoon Floating Roof offers several outstanding improvements and advantages, is simple in construction, and is provided with a positive vapor seal.

It is claimed to be particularly efficient when used for the protection of finished products in tanks too isolated for practical manifolding to expansion roof tanks or in tanks where excessive differences in filling and withdrawal may exist, such as a water terminal.

It is said, also, that this roof is ideal for the protection of "sour" crudes. The roof lies entirely on the surface of the

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Layne Well Water Systems are absolutely modern in every detail — modern in the latest and most efficient engineering principles—modern in practical and economical design—and modern in rugged, long lasting construction. Furthermore, Layne Wells are drilled and completed by exclusive Layne developed methods which enable them to produce greater quantities of water per inch of casing diameter.

Each Layne Water System is installed, tested and turned over to the owner ready to operate. The buyer, therefore looks only to Layne for fulfillment of the contract.

Layne Well Water Systems have been the choice of cities, factories, refineries, railroads, irrigation projects, mines, etc., for nearly seventy years. Thousands are in use throughout the United States and in almost every foreign country on the globe.

For further facts, details, catalogs, bulletins, etc., address Layne & Bowler, Inc., General Offices, Memphis 8, Tenn.

HIGHEST EFFICIENCY

Layne Vertical Turbine pumps are available in sizes to produce from 40 to 16,000 gallons of water per minute. High efficiency saves hundreds of dollars on power cost per year.

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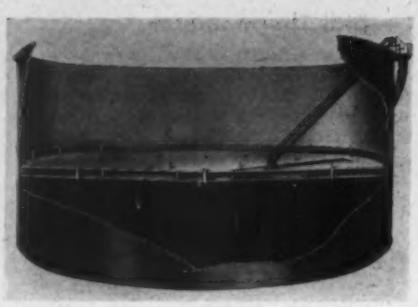
WELL WATER SYSTEMS
VERTICAL TURBINE PUMPS



Graver Pontoon Floating Roof

liquid and eliminates vapor space and the possibility of corrosion.

The Graver Pontoon Floating Roof has a double deck which is said to effectively insulate the stored liquid against boiling. It is built with a vapor-tight seal which consists of a heavily galvanized or stainless steel shoe to which is attached a synthetically treated flexible fabric. The shoe is held tightly against the tank wall by means of closely spaced spring-actuated arms. Furthermore, according to the manufacturer, the vapors collecting in the space between the roof and the tank wall further tighten the seal because of the lateral pressure they exert. When desired, a secondary seal can be installed.

The deck is designed to eliminate pockets in which dirt or water might collect. The center drain is screened with pipe drain optional, and the roof is fitted with fully adjustable supports.

CHECK THE CARD AT PAGE 233

15—Electric Hygrometer

American Instrument Company, 8010 Georgia Avenue, Silver Springs, Maryland, recently announced the Aminco-Dunmore electric hygrometer for high-precision humidity measurement and control. The instrument and its application is fully described in a 16-page bulletin, No. 184-2140.

CHECK THE CARD AT PAGE 233

16—Pyrometer

Wheelco Instrument Company, 847 W. Harrison Street, Chicago, has announced a new extension type portable pyrometer, designed to permit a choice of plug-in angle extensions where a number of applications necessitate a universal instrument for measuring and checking temperatures requiring the use of different kinds of thermocouples.

A high-resistance meter movement consists of baked, processed coils, supported by two lapped pivots resting in two highly polished sapphire resilient jewels. A magnet, highly resistant to shock, heat, vibration and stray fields provides increased ruggedness without a loss of sensitivity. Automatic compensation is a standard feature. A calibrated Briguet spiral automatically corrects every reading for variations in cold junction temperature. To protect the meter when instrument is not in use, a shunt lever is provided which can be snapped into position with a simple thumb movement.

Plug-in extensions are available in either straight, 45° or 90° angle types. Adapters permit the choice of material and calibration of thermocouples. The pyrometer is contained in a sealed, dustproof, aluminum case having a "pistol grip" handle which may be locked in a horizontal or vertical position for ease of

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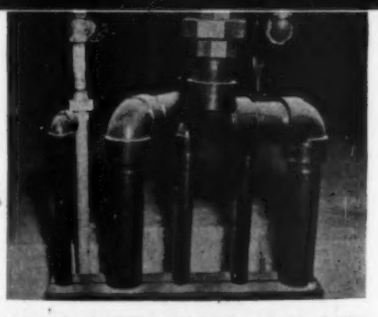

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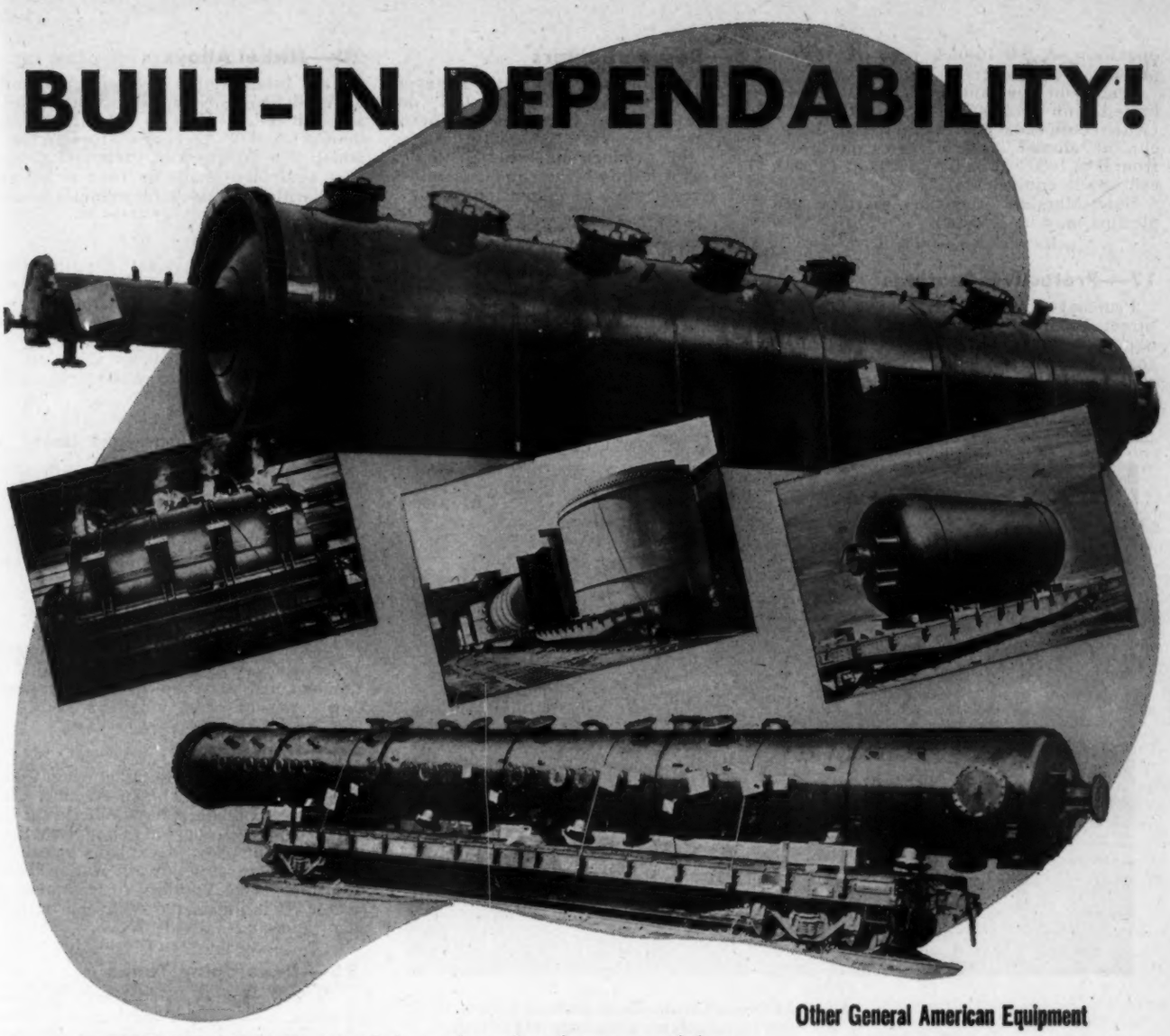

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Put this experience to work on your next plate fabrication assignment by asking for our recommendations and quotation.

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operation. A 3-9/16-inch reflector scale prevents parallax errors in reading.

Dual iron constantan scales are calibrated from 0 to 600° F. or 0 to 1000° F. (with centigrade equivalents) and dual chromel-alumel scales are calibrated from 0 to 1600° F. or 0 to 2500° F. (with centigrade equivalents).

Bare, Marshall or Surface thermocopple tips may be selected.

CHECK THE CARD AT PAGE 233

17—Protective Coatings

Prufcoat Laboratories, Inc., 63 Main Street, Cambridge 42, Masachusetts, has issued an illustrated booklet on "Prufcoat" protective coating for concrete, structural steel, floors, pipes, tanks and machinery.

CHECK THE CARD AT PAGE 233

18—Desuperheaters

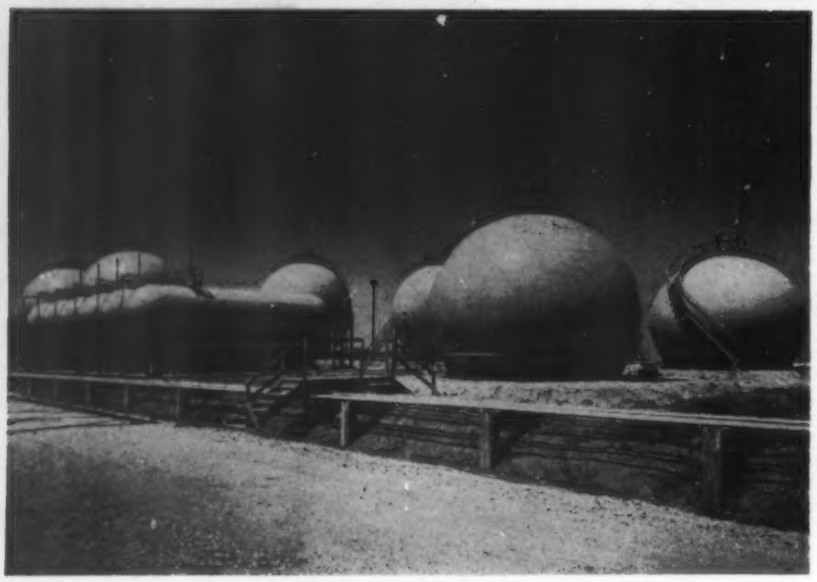
Elliott Company, Jeannette, Pennsylvania, has available Bulletin U-1, descriptive of Elliott cartridge type desuperheaters. It gives a complete description of this product, illustrates the hookup of the desuperheater and controller, and gives a table of dimensions, etc.

CHECK THE CARD AT PAGE 233

19—Fire Protection

Grinnell Company, 260 West Exchange Street, Providence 1, Rhode Island, recently has issued an illustrated booklet on "Fire Protection for Oils and Flammable Liquids." "Mulsifyre," "ProtectoSpray," and "FlameBuster" methods, all using water only, are described and illustrated.

CHECK THE CARD AT PAGE 233



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20—Nickel Alloys

The International Nickel Company, 67 Wall Street, New York 5, has available a booklet, "How to Find Long Life in Parts and Accessory Equipment," which is a directory of parts and accessory equipment made on Inco nickel alloys, with addresses of manufacturers.

CHECK THE CARD AT PAGE 233

21—Centrifuge

Centrifuge Mechanical Equipment, Inc., 95 River Street, Hoboken, New Jersey, has available a bulletin descriptive of its "Dehydrator," a "continuous flow" machine for drastic contacting of oils and various solutions with air to remove water clouds and small amounts of entrained moisture.

CHECK THE CARD AT PAGE 233

22—Portable Floodlight Unit

Consolidated Diesel Electric Corporation, Mount Vernon, New York, has available an illustrated data sheet which carries specifications on its gasoline-driven floodlight unit. The unit provides independent on-the-spot light for construction work or emergencies.

CHECK THE CARD AT PAGE 233

23—Alloys

The Cooper Alloy Foundry Company, Hillside, New Jersey, has available a new manual of technical data on heat- and corrosion-resistant alloys.

CHECK THE CARD AT PAGE 233

24—Reactivator

Graver Tank & Manufacturing Company, 332 South Michigan Avenue, Chicago, has available a new bulletin on the Graver Sludge Blanket Type Reactivator. In eight pages it explains principles and advantages of upward sludge filtration and its adaptability to treatment of water. It is illustrated with charts, flow diagrams and drawings.

CHECK THE CARD AT PAGE 233

25—Developing Tanks

Peck & Harvey, 5736 North Western Avenue, Chicago 45, has issued a folder describing and illustrating a working group of four stainless-steel developing tanks with new efficiency features in developing, fixing and washing processes.

CHECK THE CARD AT PAGE 233

26—Boiler Blowdown Valves

Strong, Carlisle & Hammond Company, 1392 West Third Street, Cleveland 13, Ohio, recently has published its Catalog 102 on continuous boiler blowdown valves and assemblies—containing a simple and non-technical explanation of the operation and desirability of continuous blowdown.

CHECK THE CARD AT PAGE 233

27—Filters

The Blackburn-Smith Manufacturing Company, 95 River Street, Hoboken, New Jersey, has a new catalog illustrating "The Refiner," a pressure leaf type filter for clarifying and polishing, and the company's line of cartridge type filters for industrial, marine and general service.

CHECK THE CARD AT PAGE 233

28—Furfural

The Quaker Oats Company Chemicals Department, 141 West Jackson Boulevard, Chicago 4, has issued two more bulletins in its series on furfural and its derivatives. Bulletin 202, "Introduction to the Chemistry of the Furans," is a 16-page booklet which

WHAT I WANT IS ACTION!

"Hang on to your nerves, boss. Armstrong's agreed to do it—but I sure hate to ask anybody to do a heat insulation job that fast."

"Why? That's their business, isn't it?"

"Sure—but it isn't their fault we didn't get the piping in earlier."

"What's the matter, Pete—you getting soft all of a sudden? The Production Department gave us just 72 hours to get that equipment operating and you're worrying about the Armstrong Cork Co."

"Yeah, but - - -"

"Didn't they say they had enough material in their warehouse to do the work?"

"I know, but - - -"

"And didn't they tell you they would send a crew first thing tomorrow morning?"

"That's right, but - - -"

"Well then, why are you so concerned about Armstrong? It seems to me that they're doing all right for themselves."

"Okay, Okay - - - but, believe me, I'm not forgetting them when we make the big change-over next spring."

We'll be pleased, Pete, if you do remember us when the time comes to let the big contract. But you don't have to grant us any special favors just because we were able to help you out of a tight spot this time.

We aren't asking for only the rush jobs—we would much prefer to work at a more normal pace—but we are glad to help out when we can. And since we have warehouse facilities and contract operations in nearly all major industrial areas, we are able to get jobs started and completed in a minimum length of time.

If you would like to know more about the reasons why we were able to help Pete, send for our free booklet, "Armstrong's Contract Service," today. We believe you will find it interesting. Just write to Armstrong Cork Company, Building Materials Division, 7507 Concord St., Lancaster, Pa., today.

ARMSTRONG'S INDUSTRIAL INSULATION

Complete Contract Service For All Temperatures

From 300° Below Zero

To 2600° Fahrenheit

covers in detail the structural formulae, nomenclature, chemical properties and formation of the furan compounds. It also describes methods of detection and analysis and contains charts showing principal reactions of furfural. Bulletin 203, "Physical Data on Furfural," is a 16-page booklet containing 13 tables and graphs covering such data as composition and density tables, vapor-pressure curve, solution temperatures, solubility of organic acids, salts, furfural gums and resins in furfural. These bulletins should be of particular interest to research workers.

CHECK THE CARD AT PAGE 233

29—Oil-Testing Instruments

Gotham Instrument Company, 149 Wooster Street, New York 12, has released a 16-page illustrated catalog, No. C-51, of instruments for testing petroleum. It lists a complete line of ASTM and API hydrometers and thermometers and many similar instruments for testing and laboratory use. Temperature and Baume-specific gravity conversion tables are included in this publication.

CHECK THE CARD AT PAGE 233

30—Instruments

The Brown Instrument Company, 4498 Wayne Avenue, Philadelphia 44, has issued Bulletin Oil-M-2, "Brown Instrumentation for the Fluid Catalytic Cracking Process." Written by D. M. Considine and R. E. Jones, this bulletin describes and illustrates with charts each step in the process, with emphasis on the instruments involved.

CHECK THE CARD AT PAGE 233

31—Thermostats and Relays

Precision Thermometer & Instrument Company, 1417 Brandywine Street, Philadelphia 30, has included significant new information on its mercurial thermostats and adjustable thermoregulators in its new Bulletin T, a 12-page catalog.

CHECK THE CARD AT PAGE 233

32—Instruments

H-B Instrument Company, 2518 North Broad Street, Philadelphia 32, has issued its Catalog No. 14, listing temperature controls, relays and thermometers.

CHECK THE CARD AT PAGE 233

33—Saran Coating Materials

The Dow Chemical Company, Plastics Division, Midland, Michigan, is distributing technical data booklets on two new Saran coating materials — Saran F-120, a solvent-soluble resin imparting very low moisture vapor transmission, and Saran F-122, a latex forming a continuous film upon air drying.

CHECK THE CARD AT PAGE 233

34—Gas Mask

Mine Safety Appliances Company, Braddock and Meade Streets, Pittsburgh, Pennsylvania, is distributing a new four-page bulletin on its M. S. A. industrial gas masks for protection against industrial gases, smokes, vapors and dusts (except carbon monoxide and illuminating gas).

CHECK THE CARD AT PAGE 233

35—Condenser Injector

Condenser Service & Engineering Company, Hoboken, New Jersey, has a bulletin on its Wizard condenser injector which stops tube leaks while the condenser continues to operate. Construction and application are explained.

CHECK THE CARD AT PAGE 233

36—Corrosion

The Dow Chemical Company, Magnesium Division, Midland, Michigan, has issued a bulletin on "How Magnesium Protects Underground Pipelines," which is a discussion of the problems of corrosion and protection against it by use of magnesium anodes on underground pipes and metal structures.

CHECK THE CARD AT PAGE 233

37—Pyrometer Supplies

The Brown Instrument Company, Accessories and Supplies Division, Philadelphia 44, has issued a buyers' guide on standard pyrometer supplies which presents information on how to order thermocouples, protecting tubes, thermocouple wire, lead wire, insulators, etc. It contains descriptions and prices on various types of standard thermocouples.

CHECK THE CARD AT PAGE 233

38—Try Cocks

Yarnall-Waring Company, Chestnut Hill, Philadelphia 18, has issued a new circular, WG-1815, on its water-column try cocks. Engineering data is given on models for pressures up to 250 pounds, and for pressures to 1500 pounds. Drawings show construction details.

CHECK THE CARD AT PAGE 233

39—Strainers and Separators

American District Steam Company, North Tonawanda, New York, has issued Bulletin No. 46-50, which gives dimensions and list prices on strainers and separators.

CHECK THE CARD AT PAGE 233

40—Blowers

Roots-Connersville Blower Corporation, Connersville, Indiana, is distributing Bulletin No. 22-23-B-12, on rotary positive blowers. It includes specifications and pertinent engineering data. Illustrated descriptions include blowers for oil refining processes and chemical process industries.

CHECK THE CARD AT PAGE 233

41—Anhydrous Ammonia

The Barrett Division, Allied Chemical & Dye Corporation, 40 Rector Street, New York 6, has issued an informative booklet on anhydrous ammonia. Included are charts showing pressure and temperature curve on anhydrous ammonia, density of liquid ammonia, and vapor pressure of aqua ammonia, together with data on packaging and handling.

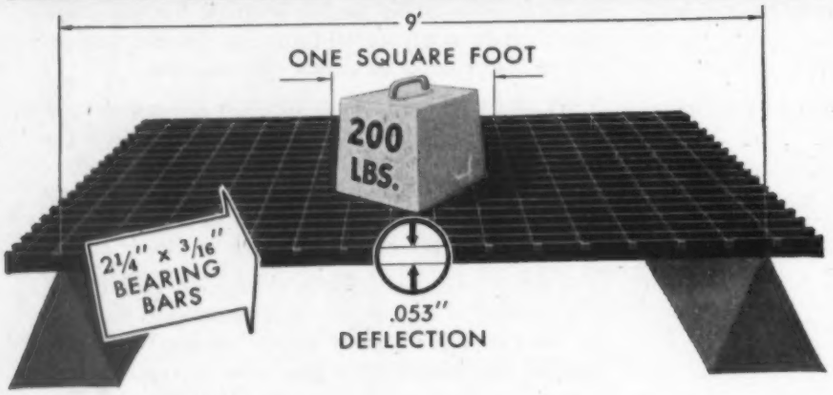
CHECK THE CARD AT PAGE 233

42—Camographs

Air Reduction Sales Company, New York City 17, has published a new bulletin describing its Airco Camographs Nos. 4 and 5 oxyacetylene cutting machines. The bulletin covers specifications, operating instructions and electrical requirements, with illustrations of both chines and has color diagrams of their respective cutting ranges.

CHECK THE CARD AT PAGE 233

This is **TRI-LOK**
OPEN STEEL FLOORING



The locked in strength of TRI-LOK enables it to stand up under heavy loads—even on long spans. No rivets, bolts or welds are used in its construction, thus, the possibility of loose joints is eliminated. *Write for Bulletin 1140.*

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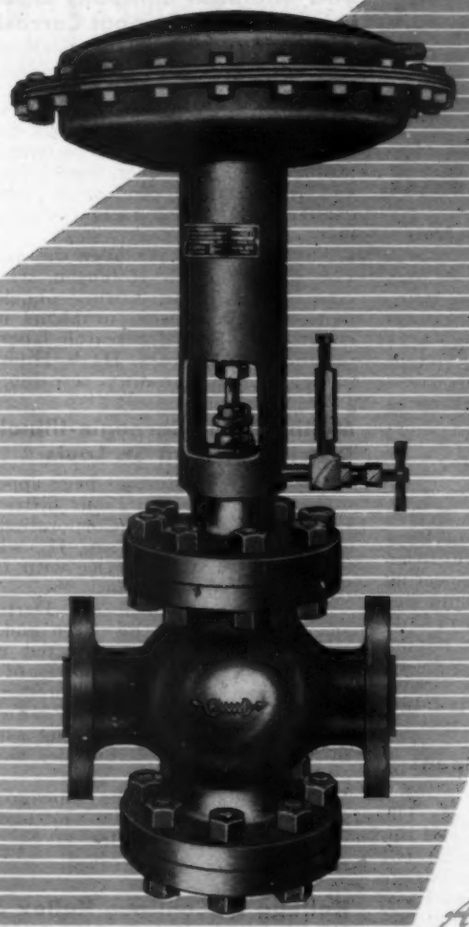
AUTOMATIC CONTROL EQUIPMENT

ENGINEERED DESIGN BY HAMMEL-DAHL

Hammel-Dahl VALVE DESIGN FEATURES



Sensitivity

Diaphragm responsive to minute loading pressure change of control instrument.

Simplicity

Unit top and body construction.

Flexibility

Valve action is reversible in field, with no additional parts, in valve trim sizes of 3/16" through 12".

Ruggedness

All-steel top and rugged construction through-out.

Safety

All-steel construction permits installation in hazardous fire areas.

Reliability

Valve plug is guided top and bottom.

Continuity of indication

Valve plug stem position indicator is standard on all models.

Accessibility for adjustments

Open window permits easier adjustment of bolted stuffing gland.

Ease of installation

Valve can be installed in a vertical pipe run with no additional superstructure support.

Standardization

All flanged valves 1¼" and larger have ASA STANDARD FACE-TO-FACE Dimensions.

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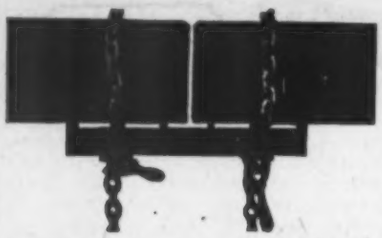

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About EQUIPMENT—SERVICE Suppliers

Claude Peavy Heads Houdry Process Design Division

Dr. Claude Peavy has been appointed to head the process design division of Houdry Process Corporation. The division is set up to perform complete process studies as well as detailed process design, in all phases of petroleum design, and is being expanded to serve particularly in the field of small plants.

Dr. Claude Peavy

Dr. Peavy received his doctor of science in chemical engineering degree at University of Michigan. Recently he has been chief process engineer in the refinery engineering division of Socony-Vacuum Oil Company, having been connected with that company eight years. Previously he was for nine years with E. B. Badger & Sons Company as process engineer.

Bury Compressor Company Elects O'Brien President

B. C. O'Brien recently was elected president and general manager of Bury Company, Erie, Pennsylvania. O'Brien is a graduate in mechanical engineering of Rose Polytechnic Institute, and has wide experience in air compressor manufacture and sales. Before joining Bury Compressor Company he was associated for a number of years with Roots-Connersville Blower Corporation as vice president and sales manager.

The Girdler Corporation Opens District Office at Tulsa

The Gas Process Division of The Girdler Corporation has announced opening of a Southwestern office at 601 Central Building, Tulsa, to be in charge of J. D. Gordon. Gordon has been Eastern representative, and has been succeeded there by D. Kenneth Finlayson, whose headquarters are at 150 Broadway, New York.

Gordon graduated from Georgia Institute of Technology in chemical engineering in 1936, and worked with Swann Chemical Company at Birmingham, Alabama, before joining The Girdler Corporation in 1939.

Finlayson received his degree in chemical engineering from Massachusetts Institute of Technology in 1935, and was with The M. W. Kellogg Company from 1936 until 1943 when he was assigned to Kellex Corporation. He joined The Girdler Corporation's Gas Process Division in December, 1945.

D. K. Finlayson

J. D. Gordon

Dow Chemical Company Opens Laboratory to Combat Corrosion

Dow Chemical Company has occupied a new laboratory in Midland, Michigan, established for study of corrosion. Emphasis will be on the study and development of magnesium for cathodic protection in industrial corrosion problems and protection of pipe lines, steel piling, oil and water tanks, condensers, heat exchangers, water heaters, and other equipment.

The laboratory is under the supervision of Harold A. Robinson, who has done similar research work on electromotive and corrosion problems in the company's physical research laboratory for the past 15 years. H. A. Humble is in charge of laboratory research.

Mullin Heads Carnegie-Illinois District Office at St. Louis

Howard J. Mullin has been appointed manager of sales, St. Louis district, for Carnegie-Illinois Steel Corporation, succeeding Robert J. Korsan, Jr., who retired after 50 years service with United States Steel Corporation.

Mullin is a graduate of Dartmouth and studied at Northwestern and Wisconsin universities. He started in the Chicago district sales office of Carnegie-Illinois Steel Corporation in 1927, and held sales positions at Milwaukee and Kansas City before being assigned to St. Louis as assistant sales manager early this year.

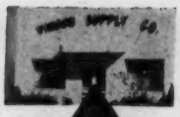
Korsan started in the Chicago office as an office boy in 1896, and had been distict manager of sales at St. Louis since 1935.

Kellogg to Continue Kellex in Widening Development Program

Plans for utilizing to their fullest peacetime value the top technical talent assembled for the development of the K-25 atom bomb plant at Oak Ridge, Tennessee, have been made known by The M. W. Kellogg Company. The plans were revealed in a statement by H. R. Austin, president, announcing that A. L. Baker had been elected vice-president of The Kellex Corporation, and W. H. Denne, Jr., general manager of the same company. The Kellex Corporation is the Kellogg subsidiary which engineered the Oak Ridge plant.

Originally formed on a war-duration basis for the sole purpose of completing the atom-bomb project, The Kellex Corporation developed a wide range of new scientific methods, procedures and equipment in the course of its work on that task. Interest in these results of its operations has become so general, Austin stated, it was decided that the technical skills and experience available could be

TULSA



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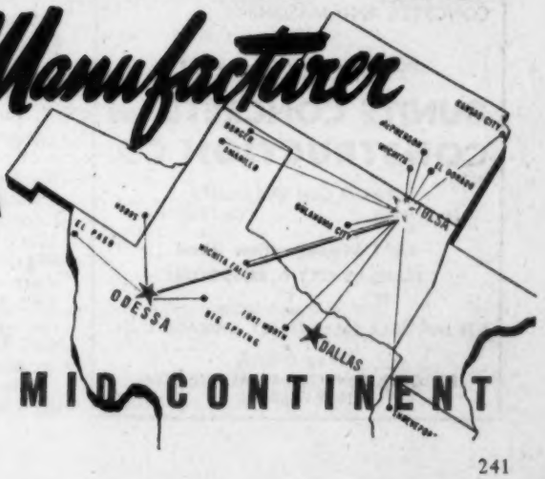

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W. H. Denne, Jr.

A. L. Baker

utilized in development work in advanced scientific fields.

Since completing the Oak Ridge project, The Kellex Corporation has been engaged on a number of studies along these new lines. The results of some of the activities are still secret. This division of the program included work in association with the Applied Physics Laboratory of the Johns Hopkins University, on the new 70-pound ram-jet engine. This engine, the Navy has currently announced, carries its "Flying Stovepipe," test vehicle for guided missiles, at a speed of 1400 miles per hour.

The election of Baker and Denne continues into peacetime operations two executives who have been actively identified with the subsidiary since its formation in 1942. Baker, as general manager, played a leading part in engineering the plant for the production of Uranium 235. Baker joined The M. W. Kellogg Company in 1934, specializing in development work on the then infant fluid catalytic-cracking process. He was chief engineer of the company in 1942 when he became project manager of The Kellex Corporation. In his new post as vice-president, he will supervise all divisions of that company's work while continuing in direct charge of the engineering and other technical operations.

Denne served The Kellex Corporation throughout the war as chief of its contracts division. In his new position he will have charge of all non-technical activities and general administration of the company.

Flotrol Systems Headquarters Being Moved to Tulsa

Warner Lewis Company, Tulsa, has acquired ownership of Flotrol Systems, Inc., and will move its headquarters from New York to Tulsa. The company manufacturers the Lewis Excel-So water separator and filter for extracting water and solids from motor fuels.

Manufacturing Chemists Elect Munson President

Charles S. Munson, U. S. Industrial Chemicals, Inc., was elected president of the Manufacturing Chemists Association of the United States at the recent annual meeting of the association. He succeeds H. L. Derby of American Cyanamid and Chemical Corporation. Leonard T. Beale, Pennsylvania Salt Manufacturing Company, and H. O. C. Ingraham, General Chemical Company, were elected vice presidents, J. W. McLaughlin, Carbide and Carbon Chemicals Corporation, was named treasurer, and Warren N. Watson was re-elected secretary.

The association, an organization of 80 chemical companies, with its headquarters at Washington, elected the following executive committee:

George W. Merck, of Merck and Company, chairman; Lammot du Pont, E. I. du Pont de Nemours, vice chairman; Mr. Derby; C. S. Hosford, Jr., Victor Chemical Works; John L. Smith, Charles Pfizer and Company; Clyde D. Marlatt, Martin Dennis Company; W. S. Landes, Celanese Corporation of America; P. T. Sharples, Sharples Chemicals, Inc.; H. I. Young, American Zinc, Lead and Smelting Company; and William M. Rand, Monsanto Chemical Company.

American Meter Advances McClenahan to Vice Presidency

American Meter Company recently announced election of R. W. McClenahan as a vice president of the company. He returned to the company after his discharge from the Army Air Force in November of last year, and has been active since that time on special assignments. Manager of the company since 1926, he was granted leave of absence in March, 1942, and was commissioned a major. His Army service included the Middle East, Africa, Europe and finally at Washington, during which time he was advanced to colonel.

R. W. McClenahan

Armour Research Foundation Dedicates Ohmite Laboratory

The Ohmite Laboratory was dedicated June 18 in all-day ceremonies at the Armour Research Foundation of Illinois Institute of Technology to serve industry of the Middle West with precision electrical measurements established on the basis of and approved by the Bureau of Standards.

Established through an endowment by David T. Siegel, president of Ohmite Manufacturing Company an a '26 graduate of Illinois Tech, the laboratory is equipped with $35,000 worth of testing and measuring apparatus that permits

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